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A BASIS FOR EVOKED POTENTIAL ASSESSMENT OF CERTAIN VISUAL FUNCT--ETC(U)
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VISUAL EVOKED POTENTIALS; VISUAL TEST; TEST BATTERY; VISUAL ACUITY; CONTRAST SENSITIVITY; SPATIAL FREQUENCY; ELECTROPHYSIOLOGY

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Evoked potential recording is a technique for recording electrical brain responses from scalp electrodes so as to assess human visual functions objectively. This report describes two evoked potential stimulators and methods for testing visual acuity and visual contrast sensitivity. These two electronic devices enable true contrast responses to be distinguished from responses to changes in local light intensity. This is achieved by dissociating the direction of contrast change from the direction of intensity change. The devices also

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allow different stimuli to be randomly interleaved under computer control. This procedure improves measurement accuracy by combining interleaving (to combat slow changes of the evoked potential with time) with signal averaging (to combat the unfavourable signal-to-noise ratio). Pattern and contrast evoked potentials are similar to those generated by the relatively inflexible optical technique, and the major EP component to pattern appearance is shown to be a true pattern response of the human visual pathway.

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A Basis for Evoked Potential Assessment of Certain Visual Functions

(b) LIST OF RESEARCH OBJECTIVES AND STATEMENT OF WORK

Final

AFOSR-80-0161 **Background**

Since evoked potential recording is a means of objectively assessing specific visual functions that are relevant to flying and hence of assessing workload, the evoked potential technique has been proposed as one element in a test battery. However, a number of specific experiments must be carried out before fully satisfactory evoked potential tests can be defined. In order to carry out these essential experiments, it is necessary to develop new forms of visual stimulation, and to establish new forms of analysis procedure. These analysis methods (involving developments of the "simultaneous stimulation" and interleaving techniques) are aimed to combat the effects of evoked potential variability and non-stationarity.

The experimental evoked potential (EP) research that was proposed under this grant fell under the following four headings: (1) Assessment of stereo vision; (2) Assessment of simple visual acuity; (3) Assessment of contrast sensitivity at medium and low spatial frequencies. Distinction between contrast evoked potentials and local luminance evoked potentials produced by pattern stimulation; (4) Methods for measuring the conduction speed of visual signals. For reasons given below only about 50% of the proposed work has been completed during the grant period (though considerably less than 50% of the total funds have been expended).

Reason why 50% of the research aims were not achieved during the one-year grant period

Due to some initial delay in establishing funding, a suitable post-doctoral assistant accepted another post, and a well-qualified graduate student had to be started on another project. I advertised the position in scientific journals and received about 30 applications from candidates interested in this type of research. I took up references for almost all of these applicants, and interviewed several. Unfortunately, none of the candidates met the demanding technical (electronic) and scientific demands of the project. Rather than appoint assistants whose abilities to meet the demands of this project were in any doubt, I continued to search for adequately qualified and capable assistants. Although assistants were found who were well qualified for other of our projects, unfortunately none were found suitable for this project during the period of the grant. In order to ensure that progress was made during the period of the grant, I undertook the technical and experimental work myself without assistants using equipment mostly borrowed from other projects and researchers. Although about 50% of the aims stated in the grant application have been achieved, due to lack of assistance, progress has been much less than I had planned and envisaged. However, expenditure has been much less than 50% of the total sum allowed, mainly because I did not intend to purchase the larger items of equipment until full achievement of the experimental aims could be confidently envisaged.

(c) STATUS OF RESEARCH EFFORT

Aims 2 & 3: Assessment of visual acuity; Assessment of contrast sensitivity at medium and low spatial frequencies and distinction between contrast EPs and local luminance EPs produced by pattern stimulation.

The major problem in interpreting evoked potentials produced by pattern stimulation is to distinguish between evoked potential components that are genuinely produced by contrast stimulation and components produced by local luminance changes (i.e. local flicker). A major proportion of all papers on pattern evoked potentials do not confront this problem. Consequently, there is a serious hidden defect in very many papers on pattern evoked potentials: they cannot be clearly interpreted since they confound contrast responses with local luminance response.

Examples of this confounding include the following findings: (a) Richards and I showed that although, as expected, evoked potential amplitude is attenuated by blurring a pattern of small checks, blurring a pattern of larger checks can increase evoked potential amplitude[(1)]; (b) I showed that high spatial frequencies are "tuned" to a temporal repetition frequency about 8 cycles per second whereas low spatial frequency responses are tuned to a frequency of about 17 cycles per second.[(2)] Thus, the shape of the grating modulation transfer function depends on the choice of temporal frequency.

Figure 1 illustrates the rationale of a test that has been developed that can counter this problem (see also Appendix 1). The test is to introduce a small luminance change into the stimulus and to compare evoked potentials recorded under the following two stimulus conditions: (a) when contrast and luminance increase simultaneously; (b) when contrast increases

while luminance decreases. This test can disentangle two constituents of pattern EPs. We have designed and constructed two visual stimulators that enable this test to be carried out and also enable the test to be combined with routine assessment of contrast sensitivity and visual acuity.[3] One stimulator generates checkerboard patterns, and the other stimulator generates sinewave grating patterns. The sinewave grating pattern stimulator also includes a multi-stimulus interleaving device that improves accuracy by reducing the effect caused by slow changes of the EP with time. Appendix 2 contains a technical description of the variable-contrast checkerboard stimulus generator and Appendix 3 contains details of the variable-contrast sinewave stimulus generator and random interleaving computer programme.

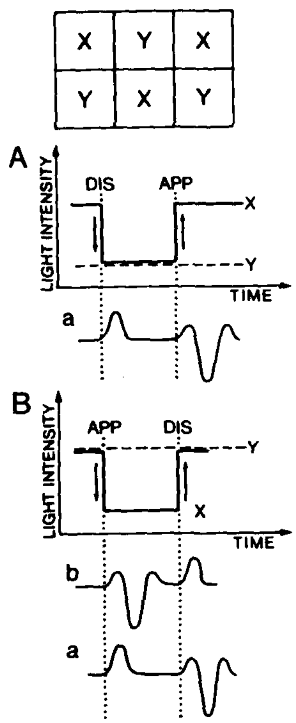

Figure 1. Test to distinguish between evoked potential components genuinely due to contrast change and evoked potential components due to changes in local luminance. See Appendix 1.

In order to dissociate responses to contrast (pattern) from responses to changes in local luminance, it is necessary to separately record EPs to the appearance and disappearance of pattern. We first described pattern appearance and disappearance responses in 1969[4,5] using an optical checkerboard-mirror stimulator. Figures 2, 3 and 4 show that our electronic checkerboard stimulator

produces pattern appearance and disappearance EPs of similar form to those obtained by the optical technique.

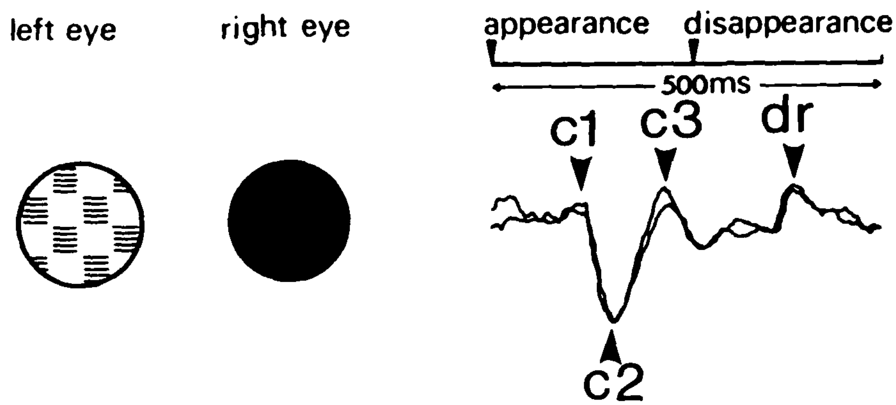

Figure 2. The appearance and subsequent disappearance of a stimulus pattern produce two quite distinguishable responses that have different cortical origins, different dynamics, different binocular summation and are differently affected by spatial frequency or check size. The appearance response consists of three components of which only C1 originates in striate cortex. Positive deflection downwards. Optical stimulator.

Components C1, C2 and C3 of the appearance EP are marked, and the pattern disappearance EP is also marked. The stimulus that generated the Figure 2 EPs involved no change of mean luminance: the transition from blank field to pattern and back again was accomplished with no change in total light flux. Figure 3 shows a recording in which increase of contrast was accompanied by a small increase of local luminance, and a recording in which the same increase of contrast was accompanied by a small decrease of local luminance.

Figure 3 demonstrates that the main component of EPs to contrast increase is indeed mainly responses to contrast change, and is not an artifact of local luminance responses. (This conclusion does not necessarily hold for all components, nor for all check sizes, nor for all

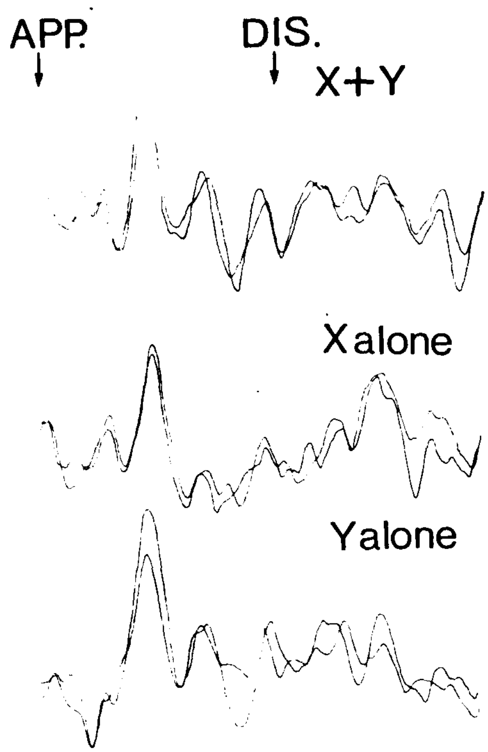

Figure 3. These evoked potentials were recorded while the subject viewed a pattern of checks that appeared (APP) and disappeared (DIS). X and Y signify alternate checks as marked in Figure 1. In the uppermost panel, checks appeared and disappeared with no change in mean luminance, since when X checks increased intensity Y checks decreased by exactly the same amount and vice versa. In the middle panel X checks only changed intensity while Y checks remained at constant intensity (Figure 1A). In the lowermost panel Y checks only changed intensity while X checks remained at constant intensity (Figure 1B). The traces show that the main appearance component was chiefly due to contrast change and not to local luminance change. Checks were 80 min arc and A + B was 80% contrast. Stimulus rate 1.2 Hz, sweep time 800 msec, 50 sweeps, two repeats. Positive upwards.

electrode positions. The test must be repeated for each new stimulus condition.) To the best of my knowledge, Figure 3 is the first time that this stimulus manipulation has been carried out for an electronically-generated stimulus. Figure 3 shows that our electronically-generated display enables verification that an EP is a genuine contrast response, and this verification can be carried out under computer control in the course of routinely measuring visual acuity or contrast sensitivity.

Now we turn to the sinewave grating stimulator. This stimulator has the following facilities: (1) Successive presentation of four predetermined

contrast levels can be interleaved so that four EPs are recorded simultaneously. This interleaving procedure combats the disturbing effect of slow EP changes with time so as to improve the accuracy of measuring EPs for different contrast levels. The interleaving procedure is carried out by specially-constructed electronics controlled by a Commodore PET microcomputer. Averaging is achieved by means of a hard-wired four-channel averaging computer (Nicolet CA-1000). Grating stimuli are displayed on a CRT made by Joyce; (2) The direction of contrast change and local luminance change can be dissociated (as described for the checkerboard stimulator) so as to verify that the sinewave grating EPs are genuine responses to contrast and are not artifacts of responses to changes in local luminance.

Figure 4 shows EPs to the appearance and disappearance of a sinewave grating pattern of spatial frequency 2.5 cycles per degree. Reading from the top, the four traces are responses to gratings of contrasts 12.5%, 25%, 50% and 100% respectively. There are 50 sweeps for each trace, and the four stimuli were randomly interleaved in blocks of four. The stimulus cycle time was 600 msec and sweep time 500 msec. Figure 4 shows how the amplitude of the C2 component of the appearance EP rapidly increases with contrast only up to a contrast of 25-50%, and then saturates at higher contrasts. The disappearance EP, on the other hand, is only evident at the highest contrasts.

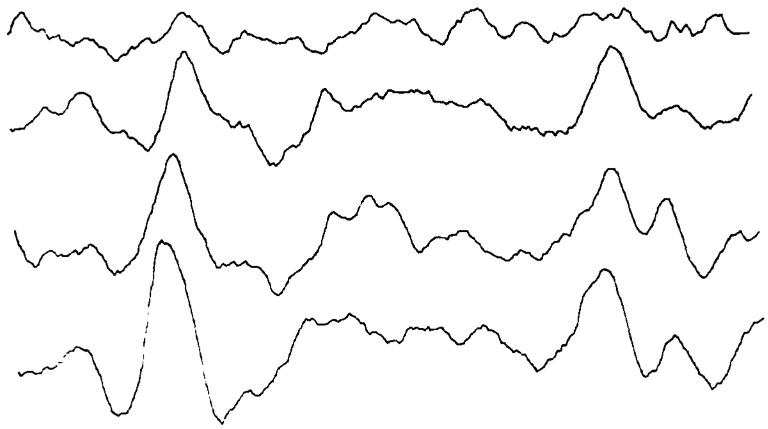

Figure 4. Averaged transient evoked potentials elicited by the appearance and disappearance of a sinewave grating pattern of spatial frequency 2.5 cycles per degree. Reading downwards from the top, contrasts were 12.5%, 25%, 50% and 100%. Fifty presentations of each contrast were recorded, interleaving in blocks of four. Stimulus cycle time 600 sec, sweep time 500 msec. Positive upwards.

Conclusions

Visual evoked potentials can be used to objectively assess visual acuity and visual contrast sensitivity.[6,7] Human visual responses to pattern and to local changes of luminance can be disentangled. Electronically-controlled visual stimulators allow rapid computer-controlled recording methods to be used.

We have shown that electronically-controlled visual displays can be constructed that are adequate in the following respects:

(a) Stimulus edges are sharp even for 10 min arc checks in a 5° field, and contrast changes are sufficiently free from luminance artifacts so that the EPs to pattern appearance and disappearance are similar to those obtained with the best optical stimulators.

(b) Switching between pattern and blank fields is sufficiently well-balanced that artifact-free contrast EPs can be recorded down to near-threshold contrast levels.

(c) The direction of contrast change and the direction of local luminance change can be dissociated, both for checkerboard and for sine-wave grating stimuli, so that verification of contrast responses can be carried out (see Figures 1 & 3).

(d) It can be arranged that both stimulus contrast and spatial frequency are under computer control, as is the memory location in the averaging computer, so that the presentations of different stimuli can be randomly interleaved by the use of appropriate software. When combined with signal averaging, this procedure improves accuracy since it minimizes the disturbing effects of EP nonstationarity.

References

(1) Regan, D. & Richards, W. Brightness contrast and evoked potentials. J. Opt. Soc. Am., 1973, 63, 606-611.

(2) Regan, D. Assessment of visual acuity by evoked potential recording: ambiguity caused by temporal dependence of spatial frequency selectivity. Vision Res., 1978, 18, 439-443.

(3) Regan, D., Beverley, K.I. & Macpherson, H. Method for rapidly recording and verifying contrast evoked potentials. 1982, in preparation.

(4) Tweel, L.H. van der, Regan, D. & Spekreijse, H. Some aspects of potentials evoked by changes in spatial brightness contrast. 7th ISCERG Symp., Istanbul (1969), pub. by Univ. of Istanbul (1971), pp. 1-11.

(5) Spekreijse, H., van der Tweel, L.H. & Regan, D. Interocular sustained suppression: correlations with evoked potential amplitude and distribution. Vision Res., 1972, 12, 521-526.

(6) Regan, D. Evoked potential studies of visual perception. Can. J. Psychol., 1981, in press.

(7) Regan, D. Comparison of transient and steady-state methods. Proc. N.Y. Acad. Sci., 1982, in press.

APPENDIX 1

Pattern stimulation does not necessarily give pattern EPs

Presenting a patterned stimulus to the eye does not necessarily give an EP that is entirely (or even partly) specific to pattern, even when there is no change in total stimulus light flux.* For example, in pattern-reversal stimulation the bright and dim checks abruptly exchange places so that there is no change in total light flux. How, then, can there be any luminance stimulation? Indeed, if the receptive-field size for the luminance mechanism is very much larger than the check size, then there will be no luminance stimulation because each receptive field will "see" zero change in total light flux. However, if the receptive field for the luminance mechanism is about the same size as a check (or smaller) and there is some nonlinear distortion before spatial summation, then there can be a luminance response. Imagine that one receptive field is stimulated by repetitive changes of intensity at a frequency F Hz. Imagine that the neighbouring receptive field is similarly stimulated but in the opposite phase, so that the first receptive field is brightest when its neighbour is darkest. (Thus, the two receptive fields are on opposite sides of the contrast border whose contrast reverses at a frequency of 2F Hz.) The point of all this is as follows: it is known that, due to a rectifier-like nonlinearity, local luminance changes at F Hz will generate distorted signals containing a component at 2F Hz, so that after spatial summation (whose effect is to cancel the F Hz signals) there will be a residual 2F Hz

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* Flashed-pattern stimulation may, of course, produce responses to luminance change as well as to pattern. In addition there may be EP components related to nonlinear interactions between luminance and pattern responses, but we do not discuss this form of stimulation here.

signal due to local luminance flicker; this residual signal has exactly the same frequency as genuine responses to contrast reversals. The important point is that this net response could occur in the absence of *any pattern response* (where a true *pattern response* is generated by a change in spatial contrast across a contrast border).

In general, an EP to pattern stimulation contains both a pattern-specific contribution and a local luminance contribution. Note that the two contributions have identical temporal repetition frequencies. As check size rises (or spatial frequency falls), the local-luminance contribution will grow relatively larger. A procedure for disentangling the two contributions has been described for pattern appearance/disappearance EPs.[8] (Note that blurring does not distinguish them). For pattern reversal EPs Bodis Wollner and Hendley[9] have discussed a way of distinguishing the two contributions.

The Amsterdam group's test is illustrated in Figure 1. The essential point is that in A, contrast decreases when total light flux decreases, whereas in B, contrast increases when total light flux decreases. Thus, changes of light flux are dissociated from contrast changes. The uppermost panel shows a check pattern with alternate checks marked "X" and "Y". The intensities of the X checks are modulated as shown in A (continuous line), and the averager is triggered by the modulating waveform. The other checks (Y) are held at a constant intensity, carefully preset to the level illustrated (dashed line). The EP in A is clearly asymmetric, but note that it is not possible to say that the right hand section is characteristic of "pattern appearance" rather than "light flux increase". In B the stimulating squares (X) are the same as in A, but the constant

intensity of the Y squares has been preset to a different level. One possible outcome is illustrated by the EP waveform b. Here the EP asymmetry has reversed, showing that the first part of the waveform is a response to pattern appearance rather than to light flux increase. A second possible outcome is illustrated by the EP waveform a. The EP asymmetry has not been reversed by the stimulus manipulation. Thus, the second part of the waveform a is a response to light flux increase, and this test has given no evidence for a true response to contrast change. A third possible outcome is intermediate between the waveforms a and b. This would mean that the waveform contained responses to both contrast change and light flux change. By way of illustration, one application of this test has been to show that electroretinograms (ERGs) elicited by pattern stimulation are most probably responses to local changes of luminance rather than genuine contrast responses.[10] Clearly, this test cannot be used when the EP is symmetric, as in the case of responses to pattern reversal.

References

(8) Tweel, L.H. van der & Spekreijse, H. Signal transport and rectification in the human evoked response system. Ann. N.Y. Acad. Sci., 1968, 156, 678-695.

(9) Bodis-Wollner, I. & Hendley, C.D. Relation of evoked potentials to pattern and local luminance detectors in the human visual system. In J.E. Desmedt (Ed.), Visual evoked potentials in man. Oxford: Clarendon Press, 1977.

(10) Spekreijse, H., van der Tweel, L.H. & Zuidema, Th. Contrast evoked responses in man. Vision Res., 1973, 13, 1566-1601.

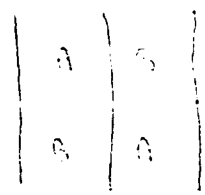
[illegible] CHECKERBOARD

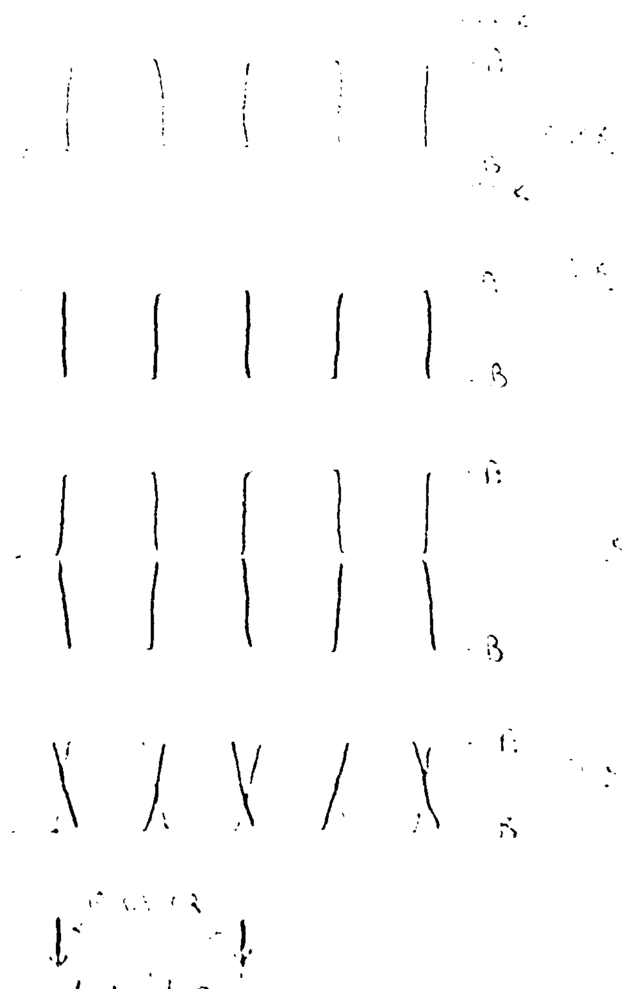
[illegible]

[illegible] 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, [illegible]

[illegible]

k = 0		k = 1		
[illegible] A (...)	CHECK B (...)	CHECK A (...)	CHECK B (...)	
2.k	2.k	[illegible]	2.k	
S1 S2	S1 S2	S1 S2	S1 S2	# 1
2.k	2.k	2.k	[illegible]	
S1 S2	S1 S2	S1 S2	S1 S2	# 2
2.k	2.k	[illegible]	[illegible]	# 3
S1 S2	S1 S2	S1 S2	S1 S2	
[illegible]	[illegible]	[illegible]	[illegible]	# 4
S1 S2	S1 S2	S1 S2	S1 S2	





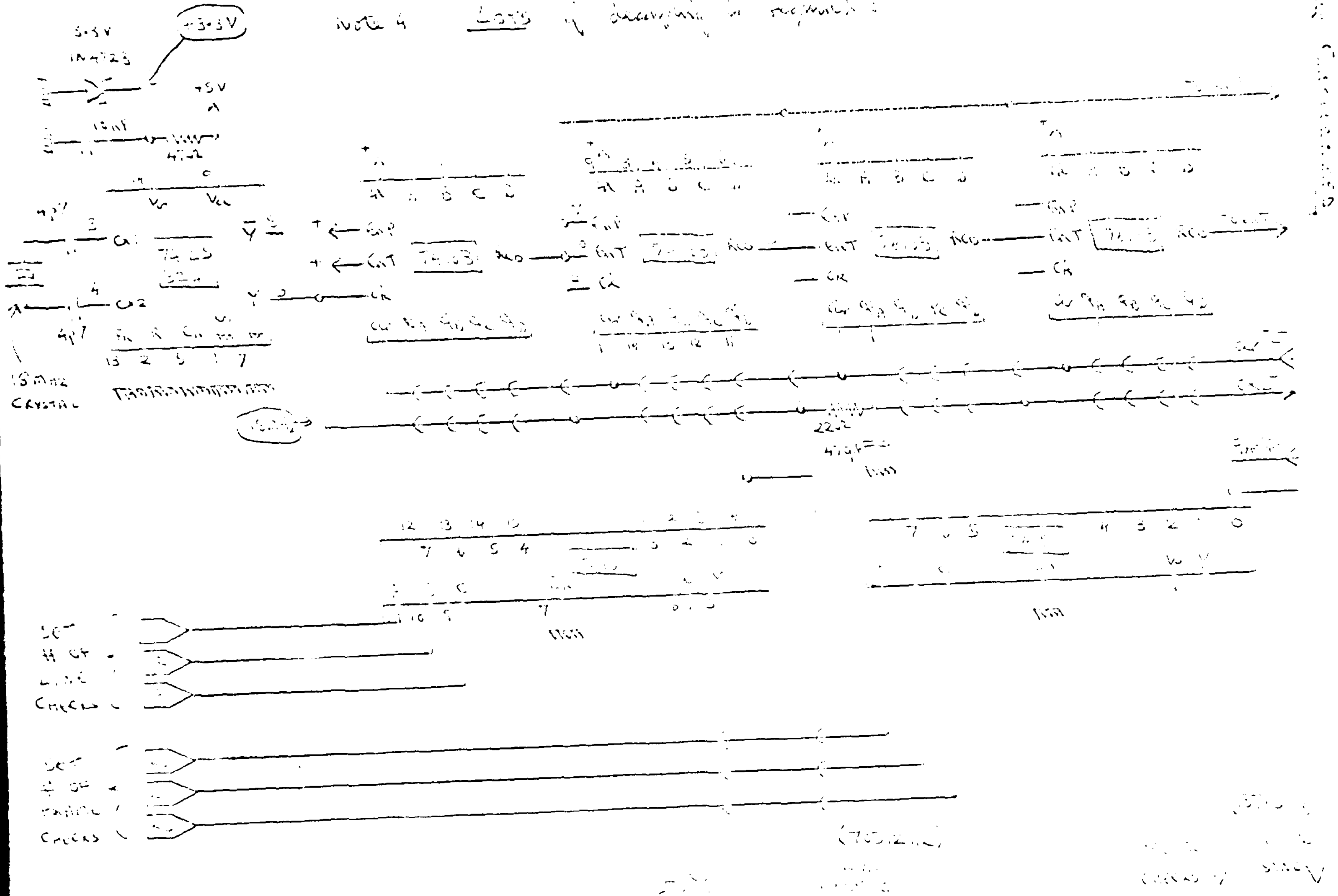
ALTERATIONS CONTINUED

Note 1 74S 24 is superior to 74LS 324

Note 2 Clock delay is necessary because of propagation delay.

Note 3 The 74151's can be replaced by a DIP SW switch if desired

Note 4 Lots of decoupling is required.



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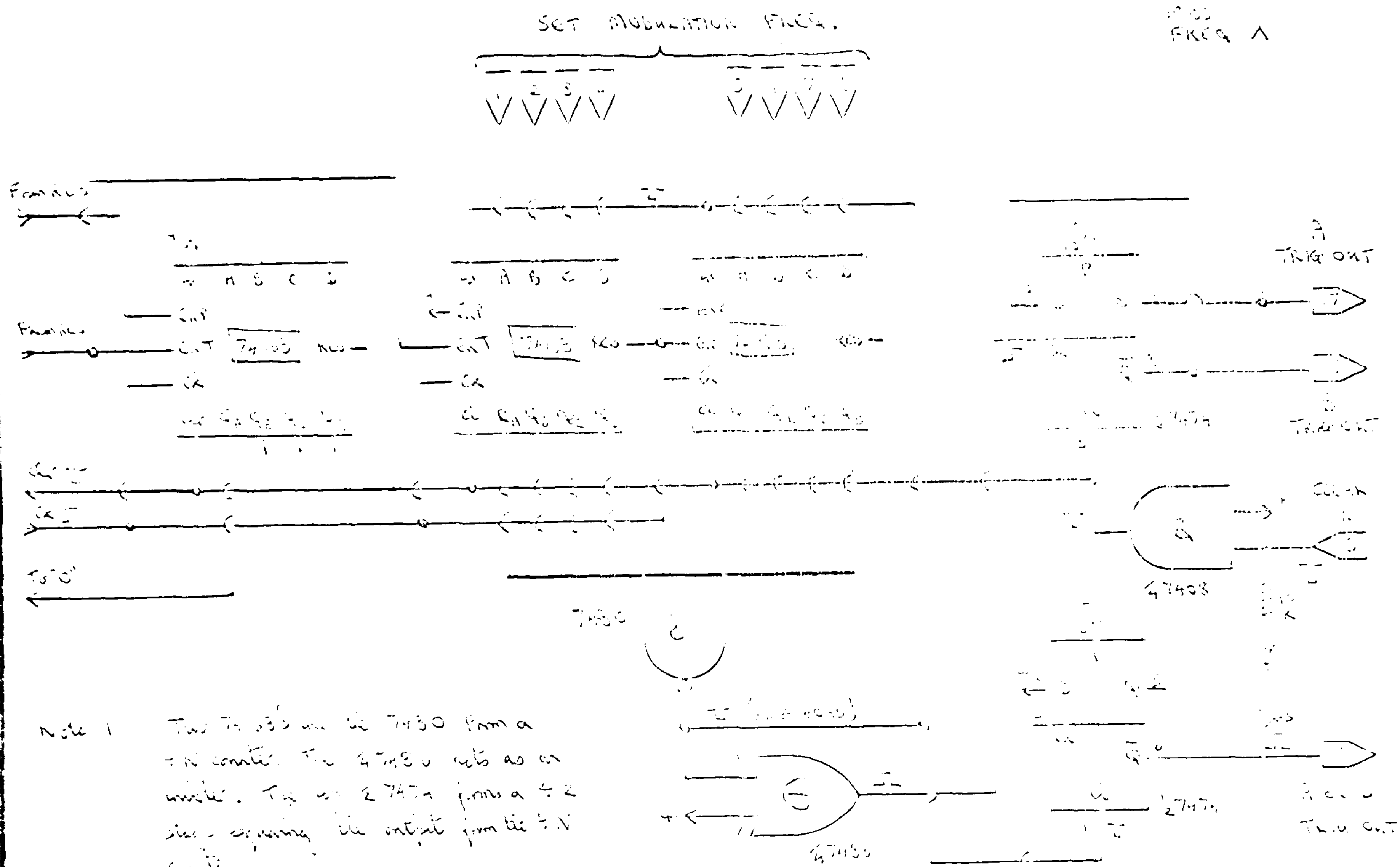


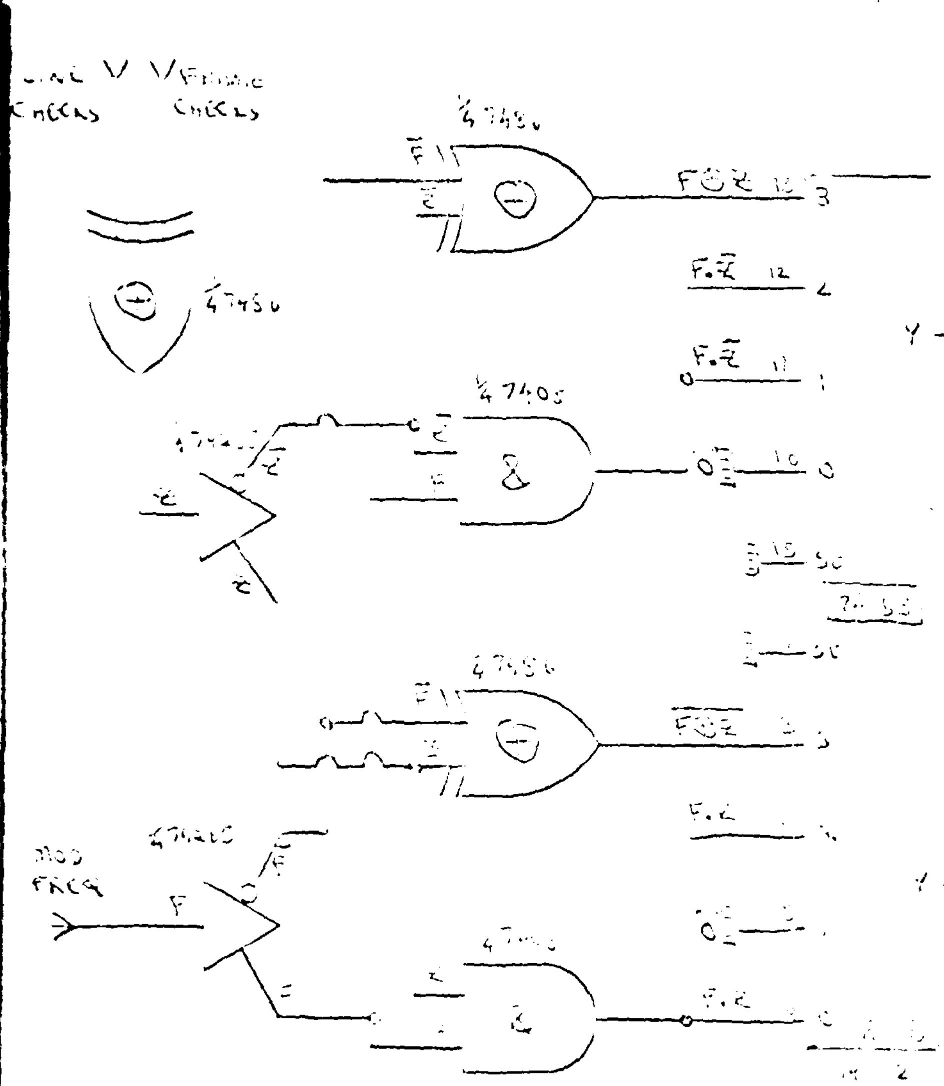
Note 1 Two 74193's and the 7430 form a ÷N counter. The 1/4 7400 acts as an inverter. The 1/2 7474 forms a ÷2 stage squaring the output from the ÷N counter.

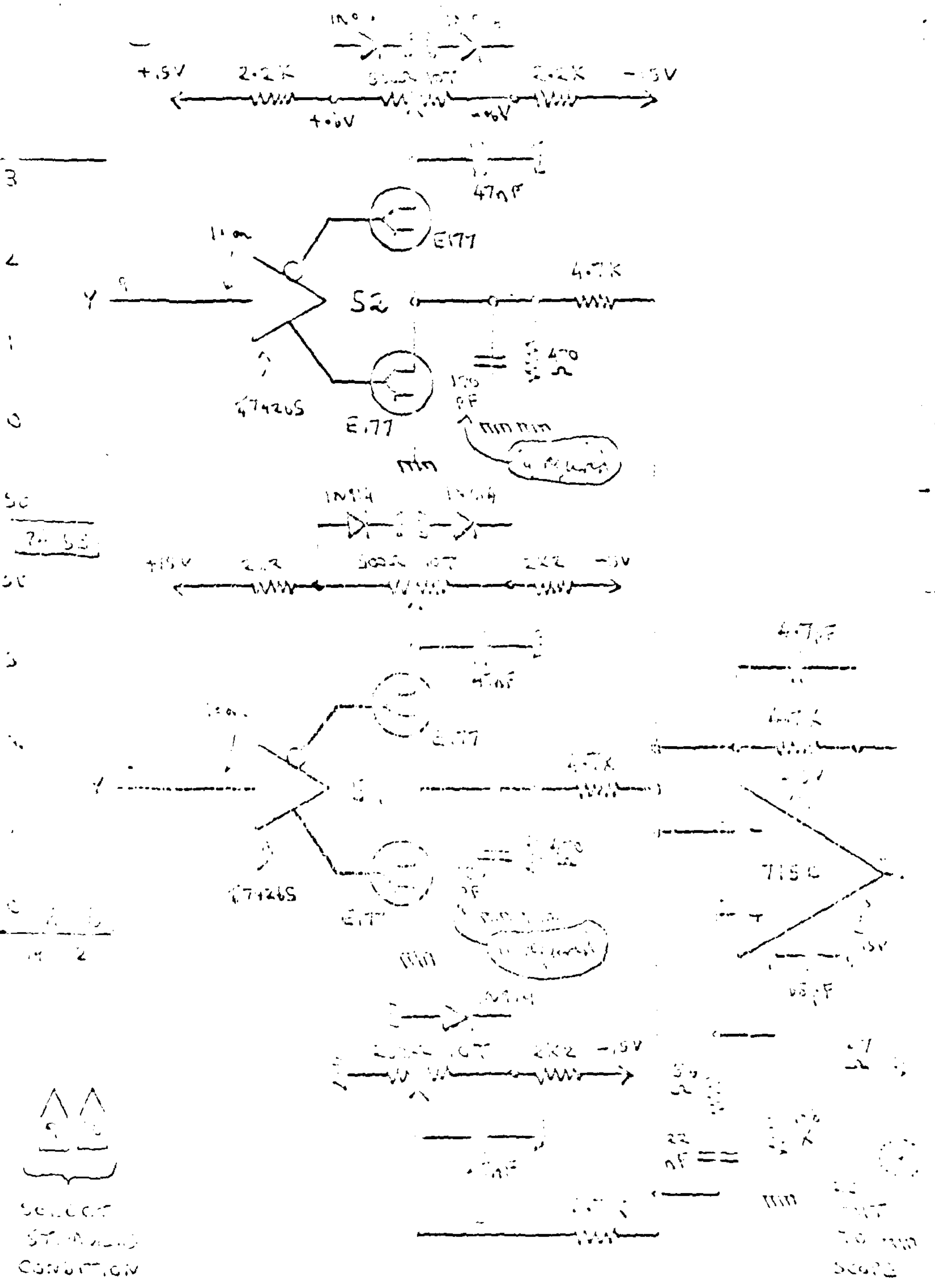
Note 2 The 1/4 7403 buffers the clock input.

Note 3 The bottom 1/2 7474 acts as a monostable making the Frame trigger pulse ≈ 15 μs.

Note 4 A trig out occurs when S2 switches on; B trig out occurs when S1 switches on.

ALTERNATING CHECKERBOARD





Note 1 74S3 can be replaced by a 2P "n" Series [illegible]

Note 2 The 150pF capacitors should be as small (possibly 0pF) as possible.

Note 3 Layout of the front half of the [illegible] is CRITICAL!

Note 4 [illegible] 3.

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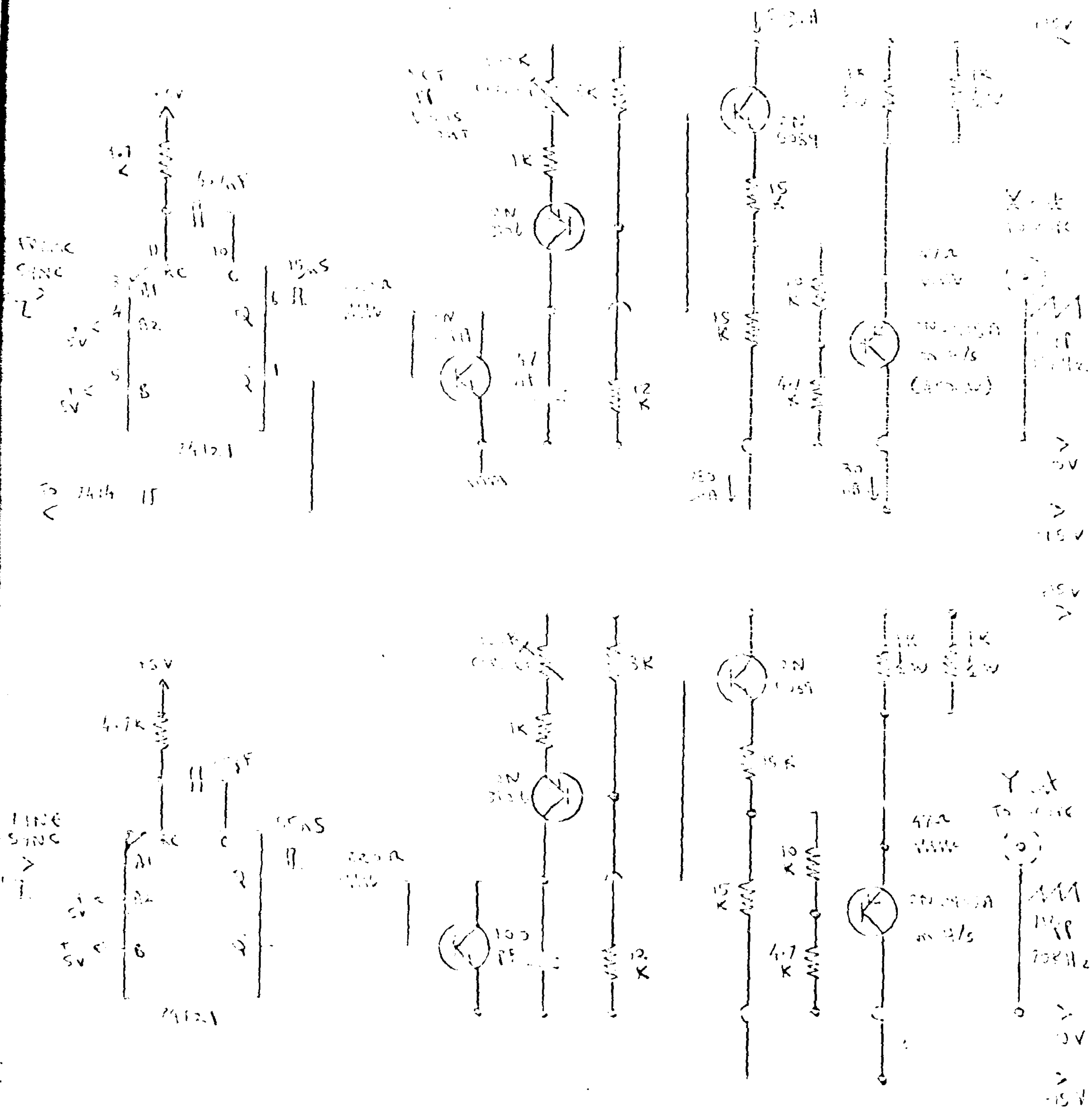

Note 1 layout of the analog part of the circuit is fairly critical

Note 2 be careful how you interconnect logic and Analog ground's.

Note 3 BNC output jacks should be isolated from the chassis.

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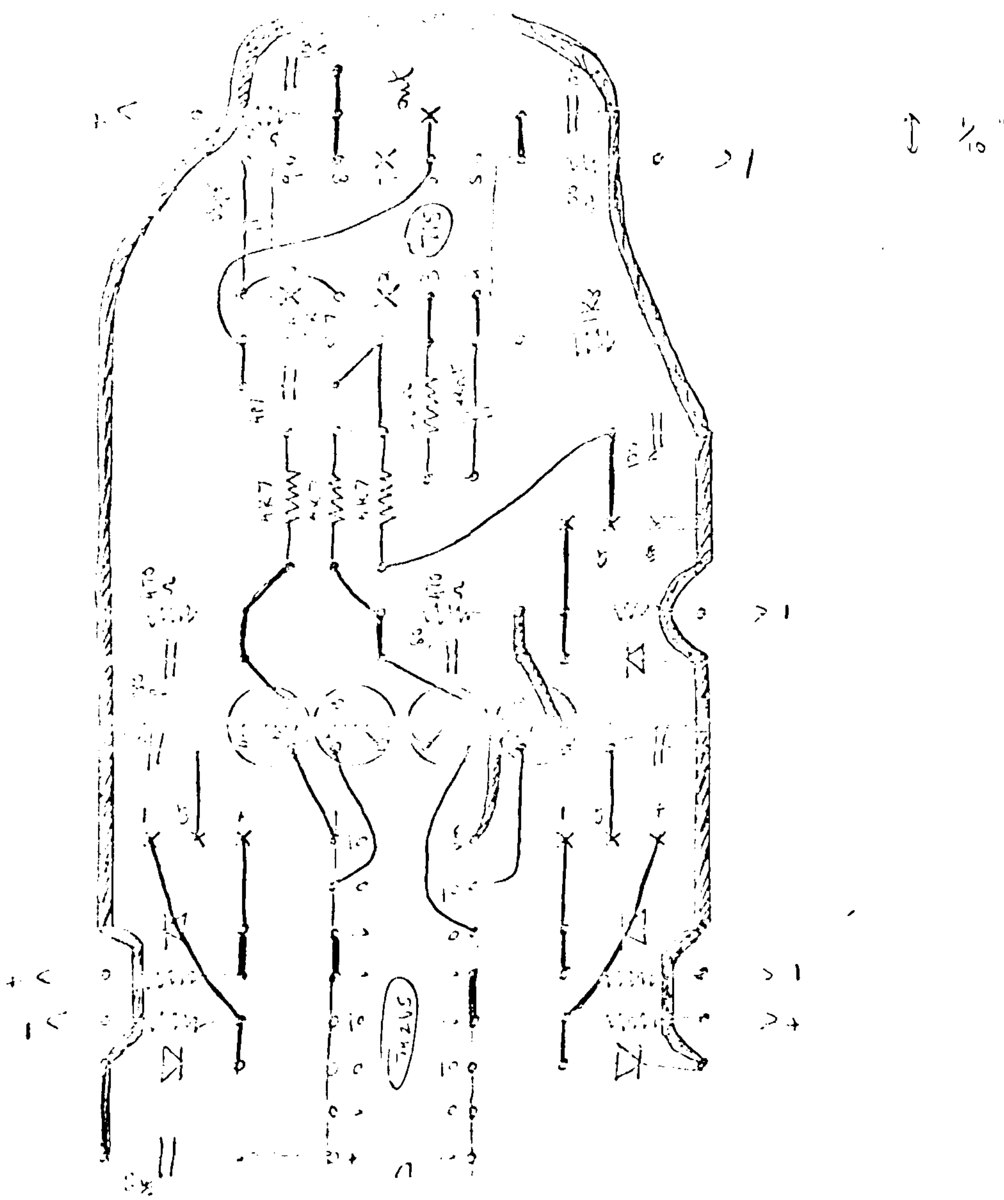
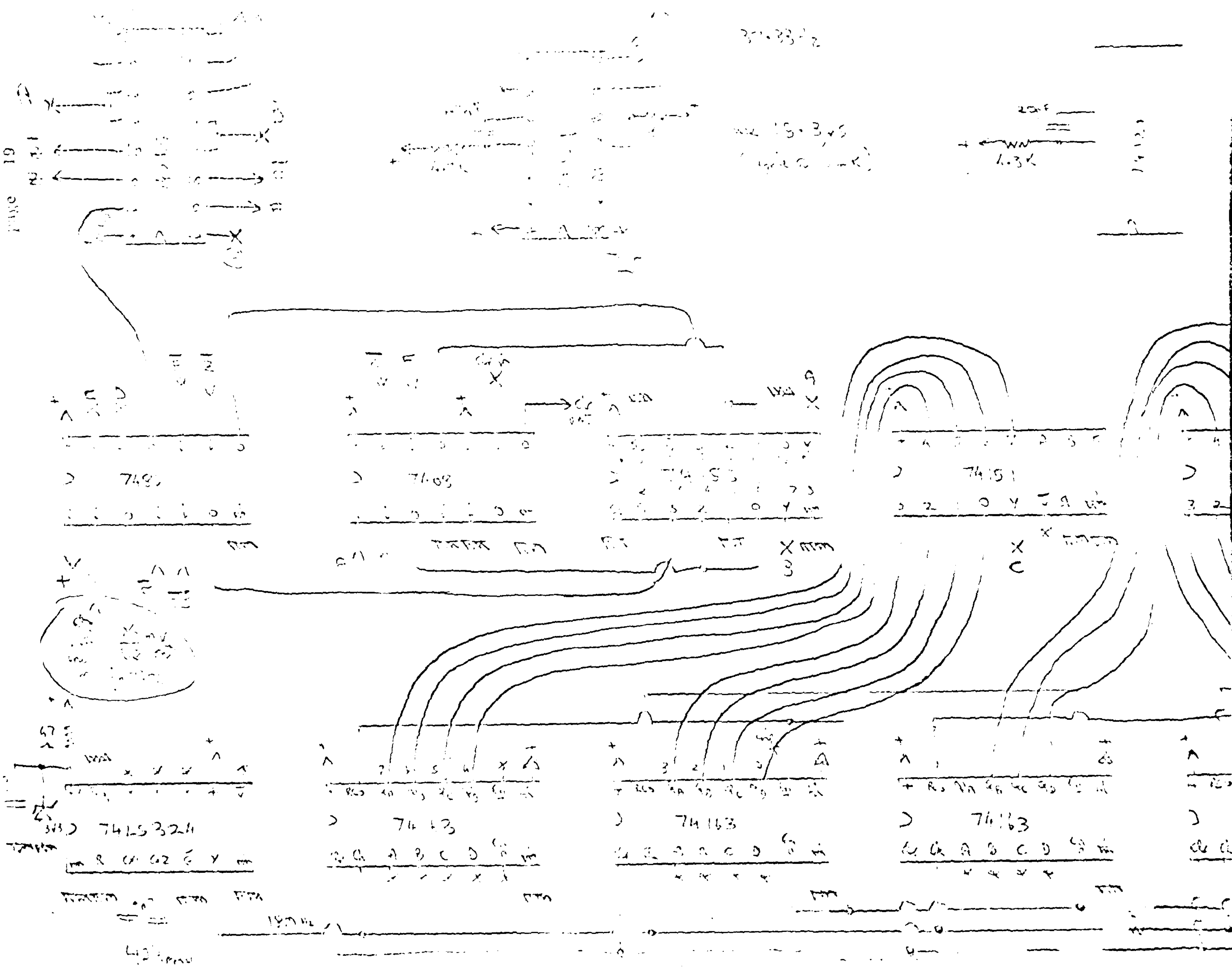


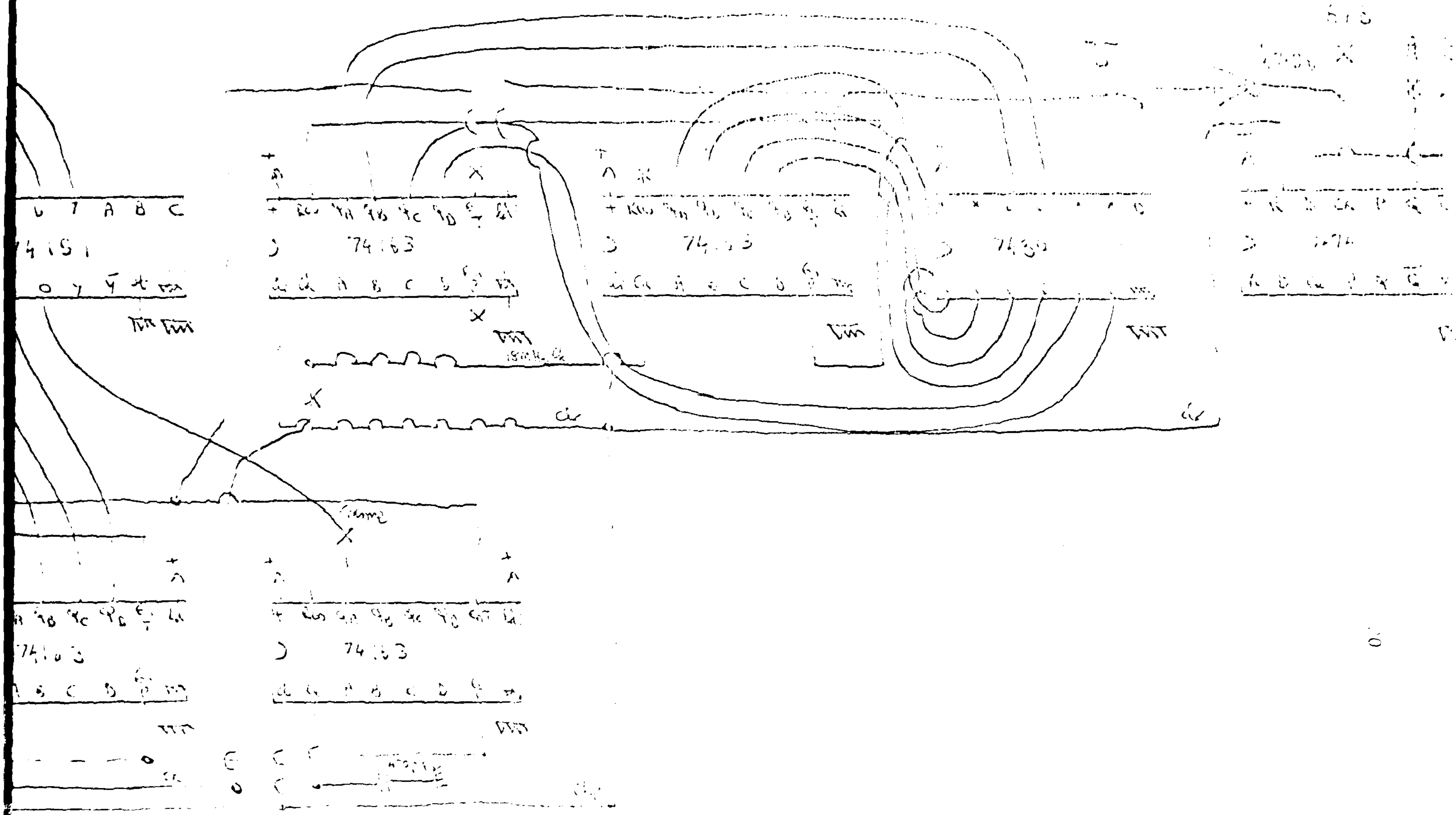
nb THIS WILL LOOK [illegible]!


74LS324
74163
74163
74163
7493
74151
4.3K

70.31 KHz

i.e. read 25 ns

wr 59.0 ns (1 cycle ...)



ALTERNATING CHECKERBOARD

PIN CONNECTIONS FOR RS 232 CONNECTOR.

1	Input	Bit 0	(LSB)	Set Modulation Frequency.
2	Input	1		
3	Input	2		
4	Input	3		
5	Input	4		
6	Input	5		
7	Input	6		
8	Input	7	(MSB)	
9	Input	A		Select Stimulus Condition #
10	Input	B		
11	Input	A		Select # of Checks / line
12	Input	B		
13	Input	C		
14	E			
15	Input	CLR		
16	E			
17	Output	Trigger Check A	(⊓)	
18	Output	Trigger Check B	(⊓)	
19	Output	Trigger Check A or Check B	(⊓) 15μs	
20	E			
21	Output	Frame Reset Pulse	(⊓) 15μs	
22	E			
23	Input	A		Select # of Checks / frame
24	Input	B		
25	Input	C		

```
100 PRINT"[illegible]GRATING [illegible] [illegible]
110 PRINT"[illegible] GRATING [illegible] [illegible]
120 PRINT"[illegible]T.
130 [illegible]:0                                   :REM INITIALIZE
140 [illegible]=1:0                                 :REM [illegible]
150 [illegible]=0                                   :REM INPUT FIXED [illegible]
160 [illegible]=0                                   :REM INPUT VARIABLE [illegible]
170 [illegible]=0                                   :REM READY TO GO
180 [illegible]* EXPERIMENTAL RUN
190 [illegible],INT(I*2/C-1.5):POKE [illegible],INT(I*5C/C+.5)[illegible]
200 [illegible]0
210 [illegible]INAL
220 FORJ=1TON
230 FORK=1TON
240 POKE[illegible]26,C(R(J)):POKE[illegible]27,D(R(J)):[illegible]2
250 NEXTK:NEXTJ
260 GOTO[illegible]0
270 REM[illegible]* [illegible]0
280 FORK=1TON
290 FORJ=1TON:R(J)=J:NEXT
300 FORJ [illegible]-1:A=1+INT(J*RND(1)):[illegible]R(J):R(J)=[illegible]:NEXT
310 FORJ=1TON
320 POKE[illegible],C(R(J)):POKE[illegible]27,D(R(J)):[illegible]2
330 NEXTJ:NEXTK
340 [illegible]* END OF RUN
350 [illegible]P,[illegible]P,[illegible]P,0              :REM STOP [illegible]
360 PRINT"[illegible]END OF RUN
370 PRINT"[illegible] ANALYSE AND/OR PRINT OUT THE DATA.
380 PRINT"[illegible]AGAIN WITH SAME PARAMETERS (Y/N)
390 [illegible]Y$"[illegible]140[illegible]01,0,150
400 [illegible]*
410 REM INITIALIZE SUBROUTINE
420 [illegible]*
430 [illegible],0,1:[illegible]E"
440 [illegible](4),D(4),R(4),[illegible](7)
450 FORJ=1TO[illegible](J-1):NEXTJ           :REM SET UP [illegible]
460 P=[illegible]471:HL=[illegible]424:CP=[illegible]426:CR=[illegible]:[illegible]457
470 POKE[illegible]459,255:POKEP,0                 :REM SET UP PORT FOR OUTPUT & CLEAR
480 POKE[illegible]468,PEEK([illegible]468)AND254          :REM SET CA1 FOR A NEGATIVE [illegible]
490 [illegible],0                                  :REM CLEAR THE PORT
500 [illegible]:[illegible]=32:16:[illegible]=32
510 [illegible]9.2                                 :REM JOYCE FRAME DURATION ([illegible])
520 RETURN
530 REM[illegible]*
540 REM FIXED PARAMETERS SUBROUTINE
550 [illegible]*
560 FOR[illegible]:NEXTJ
570 PRINT"[illegible]T # OF FRAMES/SEC ON JOYCE TO 100
580 [illegible]=100
590 PRINT"[illegible]INPUT THE FIXED EXPERIMENTAL PARAMETERS
600 PRINT"[illegible]T SCAN TIME (E.G. 5000 MILLISEC
610 PRINT"[illegible]";:GOSUB1500:SC=A
620 [illegible]1000[illegible]9000THEN[illegible]:GOTO600
630 PRINT"[illegible]ING PRESENTATION TIME (E.G. [illegible])
640 PRINT"[illegible]";:GOSUB1500:PR=A
650 IF[illegible] 100[illegible]:GOTO[illegible]0
660 RETURN
670 [illegible]*
680 REM VARIABLE PARAMETERS SUBROUTINE
```

```
190 REM ******************************
200 FOR J=1TO20:NEXT J
210 PRINT"[illegible] THE NUMBER OF [illegible]
220 PRINT"[illegible] HOW MANY CONTRAST LEVELS (1,4)
230 PRINT"[illegible]";:GOSUB 1520:NC=A
240 IF [illegible] THEN [illegible]
250 ON NC GOTO 1000,1160,1190,1100
260 PRINT"[illegible] HOW MANY REPETITIONS FOR EACH OF THE
270 PRINT NC;"CONDITIONS (E.G. 50)
280 PRINT"[illegible]";:GOSUB 1520:NR=A
290 PRINT"[illegible] # OF REPETITIONS ON [illegible] TO
300 PRINT"[illegible]
310 PRINT"[illegible] THIS WILL TAKE [illegible]";[illegible]
320 PRINT"[illegible] YOU WANT TO CHANGE YOUR MIND
330 PRINT"[illegible]";:GOSUB 1440:IF [illegible] 210
340 RETURN
350 REM ******************************
360 REM READY TO GO [illegible] ROUTINE
370 REM ******************************
380 FOR J=1TO20:NEXT J
390 PRINT"[illegible] READY TO GO
400 PRINT"[illegible] TO [illegible] PREVIOUS [illegible] ON
410 PRINT"THE [illegible].
420 PRINT"[illegible] THE [illegible] BUTTON ON THE [illegible].
430 PRINT"[illegible] TO [illegible].
440 PRINT"[illegible] TO [illegible]
450 PRINT"[illegible] IS [illegible].
460 PRINT"THIS [illegible] THE [illegible].
470 PRINT"[illegible] READY HIT 'RETURN' TO START [illegible]
480 [illegible]
490 RETURN
1000 REM ******************************
1010 REM 1 CONTRAST LEVEL SUBROUTINE
1020 REM ******************************
1030 FOR J=1TO200:NEXT J
1040 PRINT"[illegible] THERE IS 1 CONTRAST LEVEL
1050 PRINT"[illegible] WHICH CONTRAST POT DO YOU WANT (1-7)
1060 PRINT"1 [illegible]";:GOSUB 1520:IF A<1 OR A>7 THEN [illegible]
1070 PRINT"[illegible] CHANNELS 1, 2 AND 3 WILL
1080 PRINT"CONTAIN E.P.'S [illegible] WITH
1090 PRINT"[illegible], NEGATIVE AND POSITIVE
1100 PRINT"[illegible] RESPECTIVELY.
1110 PRINT"[illegible] STIMULI WILL BE [illegible] IN [illegible],
1120 PRINT"(INTERLEAVING IS IMPOSSIBLE).
1130 FOR J=1TO4:R(J)=J:NEXT J:CR=2
1140 CN=3:C(1)=1[illegible]:C(2)=2[illegible]:C(3)=3[illegible]
1150 D(1)=R(A):D(2)=R(A):D(3)=R(A):[illegible]
1160 REM ******************************
1170 REM 4 CONTRAST LEVELS SUBROUTINE
1180 REM ******************************
1190 FOR J=1TO200:NEXT J
1200 PRINT"[illegible] THERE ARE 4 CONTRAST LEVELS
1210 PRINT"[illegible] WHICH FOUR CONTRAST POTS DO YOU WANT
1220 PRINT"[illegible] FIRST CONTRAST POT IS # (1-7)
1230 PRINT"1 [illegible]";:GOSUB 1520:D(1)=A:IF A<1 OR A>7 THEN [illegible]
1240 PRINT"[illegible] SECOND CONTRAST POT IS # (1-7)
1250 PRINT"[illegible]";:GOSUB 1520:D(2)=A:IF A<1 OR A>7 THEN [illegible]
1260 PRINT"[illegible] THIRD CONTRAST POT IS # (1-7)
1270 PRINT"[illegible]";:GOSUB 1520:D(3)=A:IF A<1 OR A>7 THEN [illegible]
1280 PRINT"[illegible] FOURTH CONTRAST POT IS # (1-7)
```

```
1290 PRINT"4?";:GOSUB1520:D(4)=A:IFA<1ORA>?THENPRINTM$:GOTO1290
1300 PRINT"CHANNELS CHANNELS 1, 2, 3 AND 4 WILL
1310 PRINT"CONTAIN F.P.'S GENERATED BY CONTRAST
1320 PRINT"PLUS";D(1);D(2);D(3);"AND";D(4);"RESPECTIVELY
1330 PRINT"SOME THE GRATINGS TO HAVE ZERO, NEGATIVE
1340 PRINT"OR POSITIVE OFFSETS (0/-/+)
1350 PRINT" ?";:GOSUB1580
1360 FORJ=1TO4:D(J)=R(D(J)):NEXTJ
1370 ON 4:C(1)=10:C(2)=20:C(3)=40:C(4)=80
1380 PRINT"DO YOU WANT INTERLEAVED SEQUENCES (Y/N)
1390 PRINT" ?";:GOSUB1440:AR=A:IFAR=2THENFORJ=1TO4:R(J)=J:NEXTJ
1400 RETURN
1410 REM****************************
1420 REM INPUT Y/N SUBROUTINE
1430 REM****************************
1440 INPUT#1,A$:IFA$=""GOTO1440
1450 PRINT:IFA$<>"Y"ANDA$<>"N"THENPRINTM$:GOTO1440
1460 IFA$="Y"THENA=1
1470 IFA$="N"THENA=2
1480 RETURN
1490 REM****************************
1500 REM INPUT # SUBROUTINE
1510 REM****************************
1520 INPUT#1,A$:IFA$=""GOTO1520
1530 PRINT:A=VAL(A$):IFA=0ANDA$<>"0"THENPRINTM$:GOTO1520
1540 RETURN
1550 REM****************************
1560 REM INPUT 0/-/+ SUBROUTINE
1570 REM****************************
1580 INPUT#1,A$:IFA$=""GOTO1580
1590 PRINT:IFA$="0"THENA=RZ:RETURN
1600 IFA$="-"THENA=RM:RETURN
1610 IFA$="+"THENA=RP:RETURN
1620 PRINTM$:GOTO1580
1630 REM****************************
1640 REM MACHINE LANGUAGE SUBROUTINE
1650 REM****************************
1660 FORJ=826TO989:READA:POKEJ,A:NEXTJ:RETURN
1670 DATA 0,0,0,0,0,0,120,32,202,3,173,58,3,141,79,232,32,202,3,173,59,3,141
1680 DATA 34,232,88,169,8,205,5,2,176,249,120,173,79,232,41,64,240,249,169,0
1690 DATA 141,63,3,32,202,3,173,59,3,9,128,141,34,232,32,202,3,169,0,141,60,3
1700 DATA 32,202,3,173,79,232,41,128,13,63,3,141,63,3,173,60,3,205,61,3,208
1710 DATA 234,32,202,3,173,59,3,141,34,232,32,202,3,173,79,232,41,128,13,63,3
1720 DATA 141,63,3,173,60,3,205,62,3,208,234,169,0,141,5,2,32,202,3,173,79,232
1730 DATA 41,128,13,63,3,208,145,88,96,0,0,0,0,0,0
1740 DATA 173,65,232,173,77,232,41,2,240,249,173,60,3,24,105,1,141,60,3,96
1750 REM****************************
1760 REM SYMBOL TABLE
1770 REM****************************
1780 REM P = 59471 USER PORT
1790 REM              BITS 0-3 ARE REG RELAYS #1 TO #4
1800 REM              BIT 4 IS RELAY #5 (0 = B = NULLSET)(1 = A = OFFSET)
1810 REM              BIT 5 IS RELAY #6 (1 = A OR B)(0 = A+B = ZERO OFFSET)
1820 REM              BIT 6 IS HLTAVG IN
1830 REM              BIT 7 IS ARTIFACT IN
1840 REM RZ= 0        ZERO OFFSET
1850 REM RM=48        MINUS OFFSET
1860 REM RP=32        PLUS OFFSET
1870 REM HL= 59471 HALT AVERAGING INPUT IS BIT 6
1880 REM CP= 59426 IEEE PORT
```

```
1890 REM              BITS 0-6 ARE CONTRAST POT RELAYS #1 TO #7
1900 REM              BIT 7 IS TRIGGER OUT
1910 REM TR = 1.33    BIT FOR RICOCET TRIGGER & JOYCE SYNC TRIGGER
1920 REM J =          LOOP VARIABLE
1930 REM K =          LOOP VARIABLE
1940 REM JC = 9.2     JOYCE FRAME DURATION IN MILLISEC
1950 REM RF = 100     # OF FRAMES/SEC ON JOYCE
1960 REM SC = 500     RICOCET SCAN TIME (MILLISEC)
1970 REM PR = 500     GRATING PRESENTATION TIME (MILLISEC)
1980 REM NC = 4       # OF CONTRAST LEVELS
1990 REM CN = 4       # OF CONDITIONS
2000 REM RN = 50      # OF REPETITIONS FOR EACH CONDITION
2010 REM FR =1        RANDOMIZE FLAG
2020 REM T =          TIME
2030 REM A =          INPUT VARIABLE
2040 REM B =          INPUT VARIABLE
2050 REM A$ =         INPUT STRING
2060 REM M$ =         ERROR MESSAGE
2070 REM M1$ =        ERROR MESSAGE
2080 REM C(4) =       VALUE SENT TO USER PORT FOR EACH CONDITION
2090 REM D(4) =       VALUE SENT TO IEEE PORT FOR EACH CONDITION
2100 REM R(4) =       RANDOMIZED CONDITION #
2110 REM CP(7)=       CONTRAST POT RELAY BIT VALUES
2120 REM******************************
2130 REM RICSCAN SUBROUTINE
2140 REM******************************
2150 REM
2160 REM RICSCAN.TXT
2170 REM
2180 REM USRPRT  = 59471                     ; USER PORT LOCATION
2190 REM IEEEPT  = 59426                     ; IEEE PORT LOCATION
2200 REM CA1RST  = 59457                     ; CA1 RESET LOCATION
2210 REM CA1INP  = 59469                     ; CA1 READ LOCATION
2220 REM JFYCLK  = 517                       ; JIFFY CLOCK LOCATION (OK PET)
2230 REM REG     = 826                       ; STATE OF REG & #5 & #6 RELAYS
2240 REM CON     = 827                       ; STATE OF CONTRAST POT RELAYS
2250 REM TIME    = 828                       ; JOYCE FRAME CLOCK COUNTER
2260 REM TIME1P  = 829                       ; STIMULUS ON TIME IN FRAMES
2270 REM TIMESC  = 830                       ; RICOLET SCAN TIME IN FRAMES
2280 REM ARTIF   = 831                       ; ARTIFACT FLAG
2290 REM START   = 832
2300 REM
2310 REM START  SEI                          ; DISABLE INTERRUPT
2320 REM        JSR  WAITCA                  ; SET UP REG & #5 & #6 RELAYS
2330 REM        LDA  REG
2340 REM        STA  USRPRT
2350 REM
2360 REM        JSR  WAITCA                  ; SET UP CONTRAST POT RELAYS
2370 REM        LDA  CON
2380 REM        STA  IEEEPT
2390 REM LOOP6  CLI                          ; ENABLE INTERRUPT
2400 REM
2410 REM LOOP5  LDA  #3                      ; WAIT 3+1 JIFFIES FROM END OF SCAN
2420 REM        CMP  JFYCLK
2430 REM        BCS  LOOP5                   ; CARRY FLAG RESET WHEN JFYCLK>3
2440 REM
2450 REM        SEI                          ; DISABLE INTERRUPT
2460 REM LOOP1  LDA  USRPRT                  ; WAIT DLAYAV<>0
2470 REM        AND  #40
2480 REM        BEQ  LOOP1
```

```
2470 REM
2480 REM           LDA   #0          ! RESET ARTIFACT FLAG
2490 REM           STA   ARTIF
2500 REM
2510 REM           JSR   WAITCA      ! SET TRIGGER OUT
2520 REM           LDA   CON
2530 REM           ORA   #30
2540 REM           STA   IFFLPT
2550 REM
2560 REM           JSR   WAITCA      ! ********** STIMULUS ONSET
2570 REM           LDA   #0
2580 REM           STA   TIME        ! RESET TIMER
2590 REM
2600 REM LOOP3     JSR   WAITCA      ! WAIT END OF PRESENTATION
2610 REM           LDA   USERPT
2620 REM           AND   #30         ! -1 IF ARTIFACT
2630 REM           ORA   ARTIF
2640 REM           STA   ARTIF
2650 REM           LDA   TIME
2660 REM           CMP   TIMEIP
2670 REM           BNE   LOOP3
2680 REM
2710 REM           JSR   WAITCA      ! RESET TRIGGER OUT
2720 REM           LDA   CON
2730 REM           STA   IFFLPT
2740 REM
2750 REM LOOP4     JSR   WAITCA      ! ********* STIMULUS OFFSET
2760 REM           LDA   USERPT
2770 REM           AND   #30         ! WAIT END OF SCAN
2780 REM           ORA   ARTIF
2790 REM           STA   ARTIF
2800 REM           LDA   TIME
2810 REM           CMP   TIMESC
2820 REM           BNE   LOOP4
2830 REM
2840 REM           LDA   #0
2850 REM           STA   JFYCLK      ! CLEAR JIFFY CLOCK
2860 REM
2870 REM           JSR   WAITCA      ! CHECK ARTIFACT
2880 REM           LDA   USERPT
2890 REM           AND   #30
2900 REM           ORA   ARTIF
2910 REM           BNE   LOOP6       ! IF ARTIFACT RE-PRESENT STIMULUS
2920 REM
2930 REM           CLI               ! ENABLE INTERRUPT
2940 REM           RTS               ! EXIT TO BASIC
2950 REM
2960 REM WAITCA    LDA   CA1RST      ! WAIT CA1 SUBROUTINE
2970 REM LOOP      LDA   CA1INP
2980 REM           AND   #2
2990 REM           BEQ   LOOP
3000 REM
3010 REM           LDA   TIME        ! INCREMENT TIME
3020 REM           CLC
3030 REM           ADC   #1
3040 REM           STA   TIME
3050 REM           RTS
3060 REM
3070 REM*! ***************************
3080 REM L[illegible]RUN ASSEMBLED
```

```
3090 REM*****************************
3100 REM
3110 REM COMMUN.BIN
3120 REM
3130 REM 826 ! 033A ! 00       !   0
3140 REM 827 ! 033B ! 00       !   0
3150 REM 828 ! 033C ! 00       !   0
3160 REM 829 ! 033D ! 00       !   0
3170 REM 830 ! 033E ! 00       !   0
3180 REM 831 ! 033F ! 00       !   0
3190 REM 832 ! 0340 ! 78       ! 120
3200 REM 833 ! 0341 ! 20 CA 03 !  32 202   3
3210 REM 836 ! 0344 ! AD 3A 03 ! 173  58   3
3220 REM 839 ! 0347 ! 8D 4F E8 ! 141  79 232
3230 REM 842 ! 034A ! 20 CA 03 !  32 202   3
3240 REM 845 ! 034D ! AD 3B 03 ! 173  59   3
3250 REM 848 ! 0350 ! 8D 22 E8 ! 141  34 232
3260 REM 851 ! 0353 ! 58       !  88
3270 REM 852 ! 0354 ! A9 08    ! 169   8
3280 REM 854 ! 0356 ! CD 05 02 ! 205   5   2
3290 REM 857 ! 0359 ! B0 F9    ! 176 249
3300 REM 859 ! 035B ! 78       ! 120
3310 REM 860 ! 035C ! AD 4F E8 ! 173  79 232
3320 REM 863 ! 035F ! 29 40    !  41  64
3330 REM 865 ! 0361 ! F0 F9    ! 240 249
3340 REM 867 ! 0363 ! A9 00    ! 169   0
3350 REM 869 ! 0365 ! 8D 3F 03 ! 141  63   3
3360 REM 872 ! 0368 ! 20 CA 03 !  32 202   3
3370 REM 875 ! 036B ! AD 3B 03 ! 173  59   3
3380 REM 878 ! 036E ! 09 80    !   9 128
3390 REM 880 ! 0370 ! 8D 22 E8 ! 141  34 232
3400 REM 883 ! 0373 ! 20 CA 03 !  32 202   3
3410 REM 886 ! 0376 ! A9 00    ! 169   0
3420 REM 888 ! 0378 ! 8D 3C 03 ! 141  60   3
3430 REM 891 ! 037B ! 20 CA 03 !  32 202   3
3440 REM 894 ! 037E ! AD 4F E8 ! 173  79 232
3450 REM 897 ! 0381 ! 29 80    !  41 128
3460 REM 899 ! 0383 ! 0D 3F 03 !  13  63   3
3470 REM 902 ! 0386 ! 8D 3F 03 ! 141  63   3
3480 REM 905 ! 0389 ! AD 3C 03 ! 173  60   3
3490 REM 908 ! 038C ! CD 3D 03 ! 205  61   3
3500 REM 911 ! 038F ! D0 EA    ! 208 234
3510 REM 913 ! 0391 ! 20 CA 03 !  32 202   3
3520 REM 916 ! 0394 ! AD 3B 03 ! 173  59   3
3530 REM 919 ! 0397 ! 8D 22 E8 ! 141  34 232
3540 REM 922 ! 039A ! 20 CA 03 !  32 202   3
3550 REM 925 ! 039D ! AD 4F E8 ! 173  79 232
3560 REM 928 ! 03A0 ! 29 80    !  41 128
3570 REM 930 ! 03A2 ! 0D 3F 03 !  13  63   3
3580 REM 933 ! 03A5 ! 8D 3F 03 ! 141  63   3
3590 REM 936 ! 03A8 ! AD 3C 03 ! 173  60   3
3600 REM 939 ! 03AB ! CD 3E 03 ! 205  62   3
3610 REM 942 ! 03AE ! D0 EA    ! 208 234
3620 REM 944 ! 03B0 ! A9 00    ! 169   0
3630 REM 946 ! 03B2 ! 8D 05 02 ! 141   5   2
3640 REM 949 ! 03B5 ! 20 CA 03 !  32 202   3
3650 REM 952 ! 03B8 ! AD 4F E8 ! 173  79 232
3660 REM 955 ! 03BB ! 29 80    !  41 128
3670 REM 957 ! 03BD ! 0D 3F 03 !  13  63   3
3680 REM 960 ! 03C0 ! D0 91    ! 208 145
```

```
3690 REM 962 ! 0302 ! 58       !  88
3700 REM 963 ! 0303 ! 60       !  96
3710 REM 964 ! 0304 ! 00       !   0
3720 REM 965 ! 0305 ! 00       !   0
3730 REM 966 ! 0306 ! 00       !   0
3740 REM 967 ! 0307 ! 00       !   0
3750 REM 968 ! 0308 ! 00       !   0
3760 REM 969 ! 0309 ! 00       !   0
3770 REM 970 ! 030A ! AD 41 E8 ! 173  65 232
3780 REM 973 ! 030D ! AD 40 E8 ! 173  64 232
3790 REM 976 ! 0310 ! 29 02    !  41   2
3800 REM 978 ! 0312 ! F0 F9    ! 240 249
3810 REM 980 ! 0314 ! AD 3C 03 ! 173  60   3
3820 REM 983 ! 0317 ! 18       !  24
3830 REM 984 ! 0318 ! 69 01    ! 105   1
3840 REM 986 ! 031A ! 8D 3C 03 ! 141  60   3
3850 REM 989 ! 031D ! 60       !  96
READY.
```

[illegible]

[illegible]

Switch on PET -> MESSAGE APPEARS
Check cassette is in recorder
Type LOAD then hit 'Return' -> PRESS PLAY ON TAPE #1
Press 'Play' -> O K
-> SEARCHING
-> FOUND SIN GRAT LP 16
-> LOADING

While PET is loading:-
Switch on Joyce (check it is set to 100 [illegible])
Switch on Hewlett
Switch on Nicolet
-> READY

Rewind the cassette
Type ?ST then hit 'Return' -> 0 READY
If not 0 then there has been a load error. Switch off PET and try again. If two load errors, contact K.I.B
Type RUN then hit 'Return' -> The program starts
Switch on Flash/[illegible] box
Follow instructions of the program CAREFULLY

NOTES 1) Hit 'Return' after every entry

2) Many entries have a default value (it appears beside the flashing cursor). Simply hitting 'Return' will enter this value. To alter the value type the new value over the old and hit 'Return'

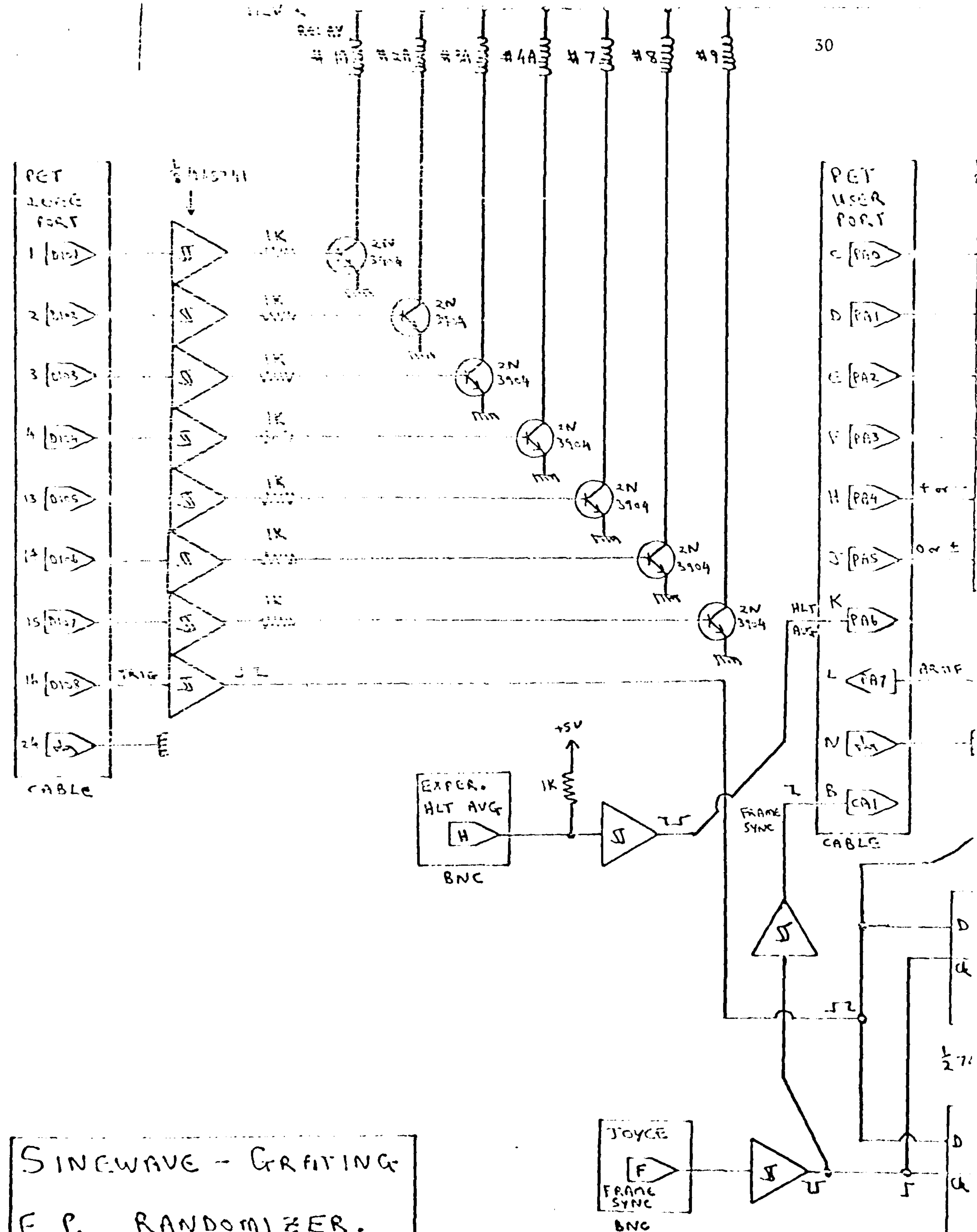
3) Each question has only a limited range of acceptable answers. Where possible this is given in brackets after the question. If you need a value outside this range you will have to contact K.I.B (and it probably will not be possible, anyway).

4) If you want the grating to be presented with approximately equal on and off intervals, then:-
2 x grating presentation time must = Nicolet scan time + 125 ms.

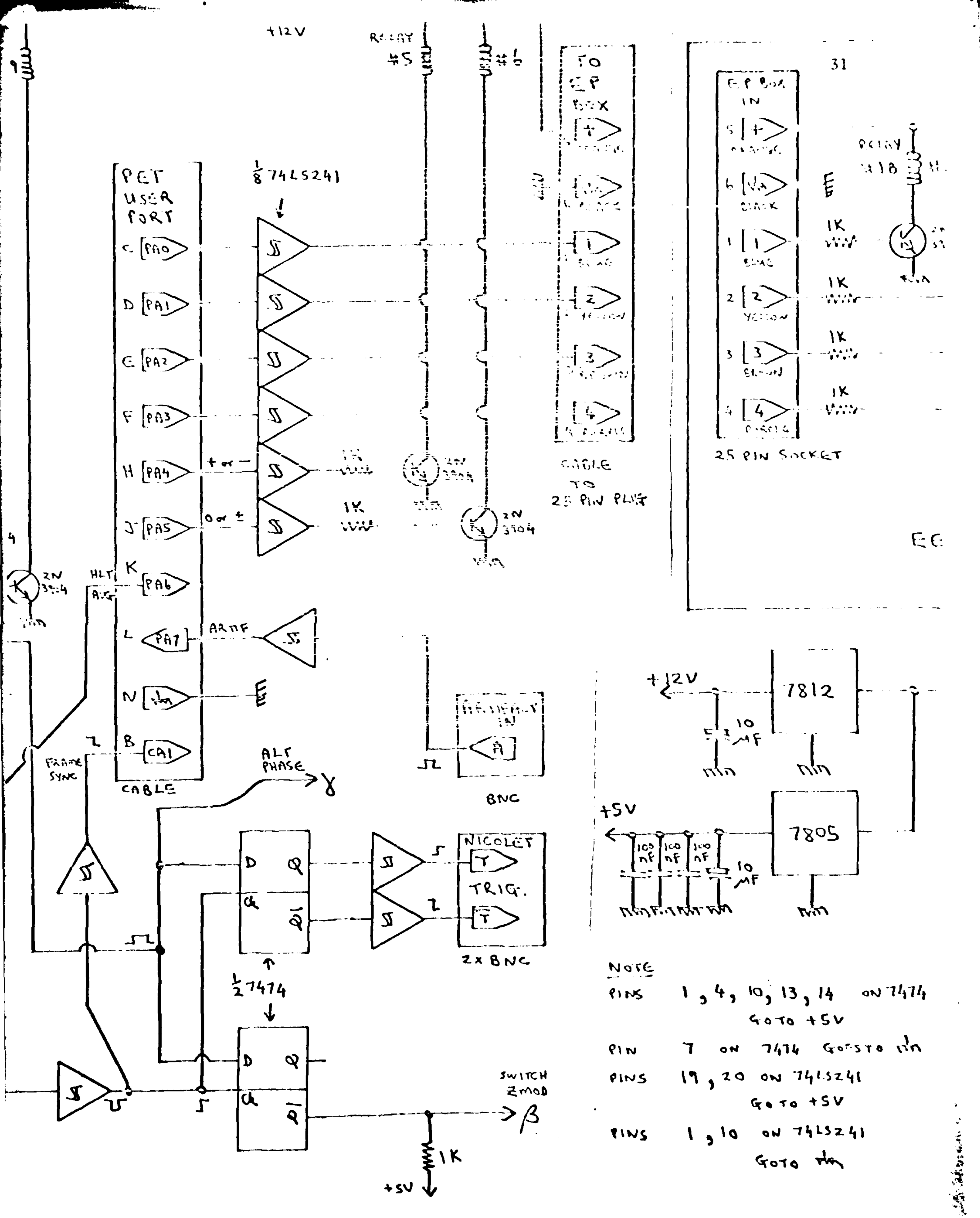
5) It is not possible to have GPT < 20mS or GPT > NST - 100mS

[illegible] CALIBRATION:-

Pot #1	=	12.5% Contrast
#2	=	25%
#3	=	50%
#4	=	100%
#5	=	6.25%
#6	=	33.3%
#7	=	66.7%



SINEWAVE - GRATING
E.P. RANDOMIZER.



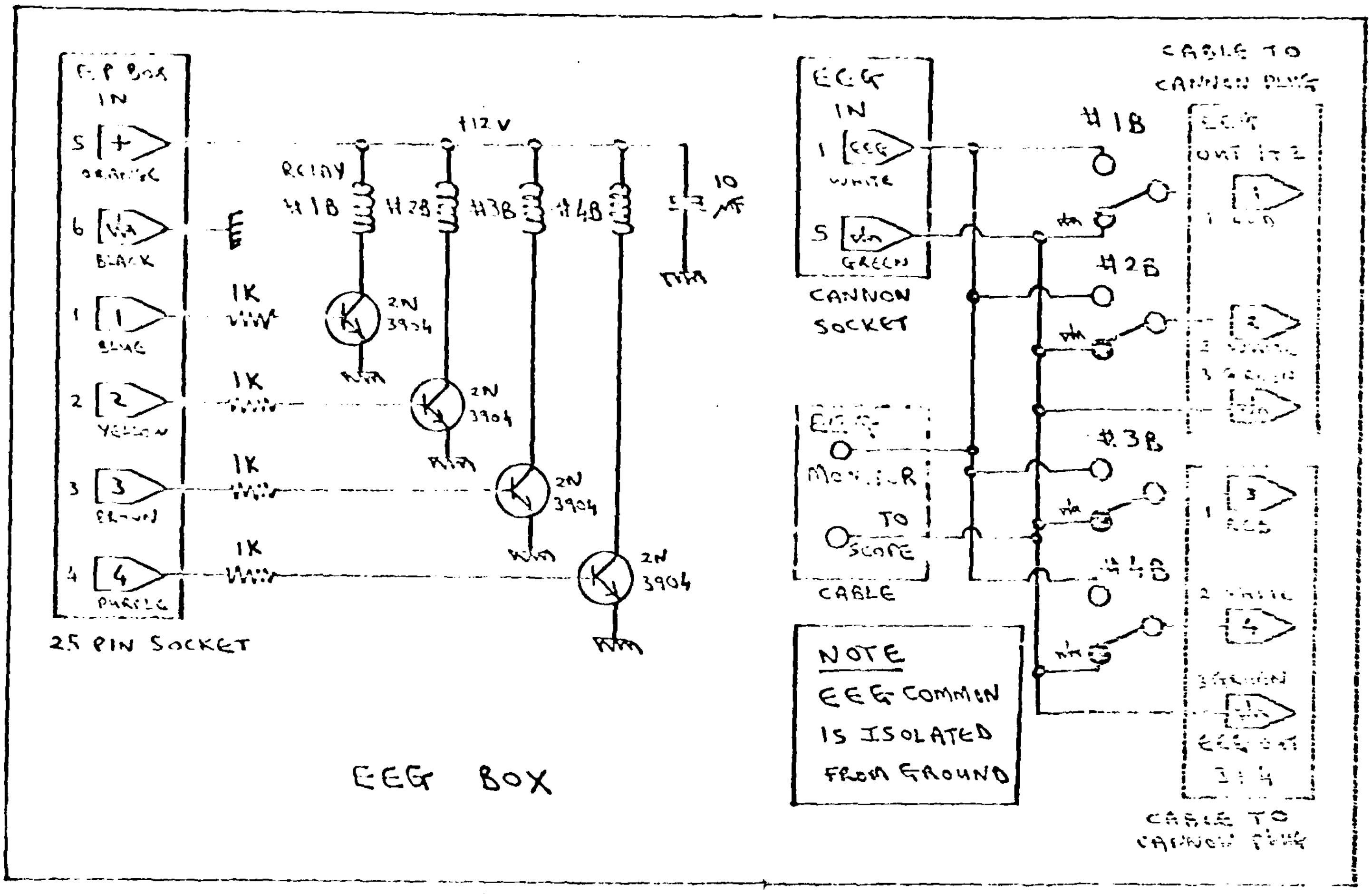
NOTE

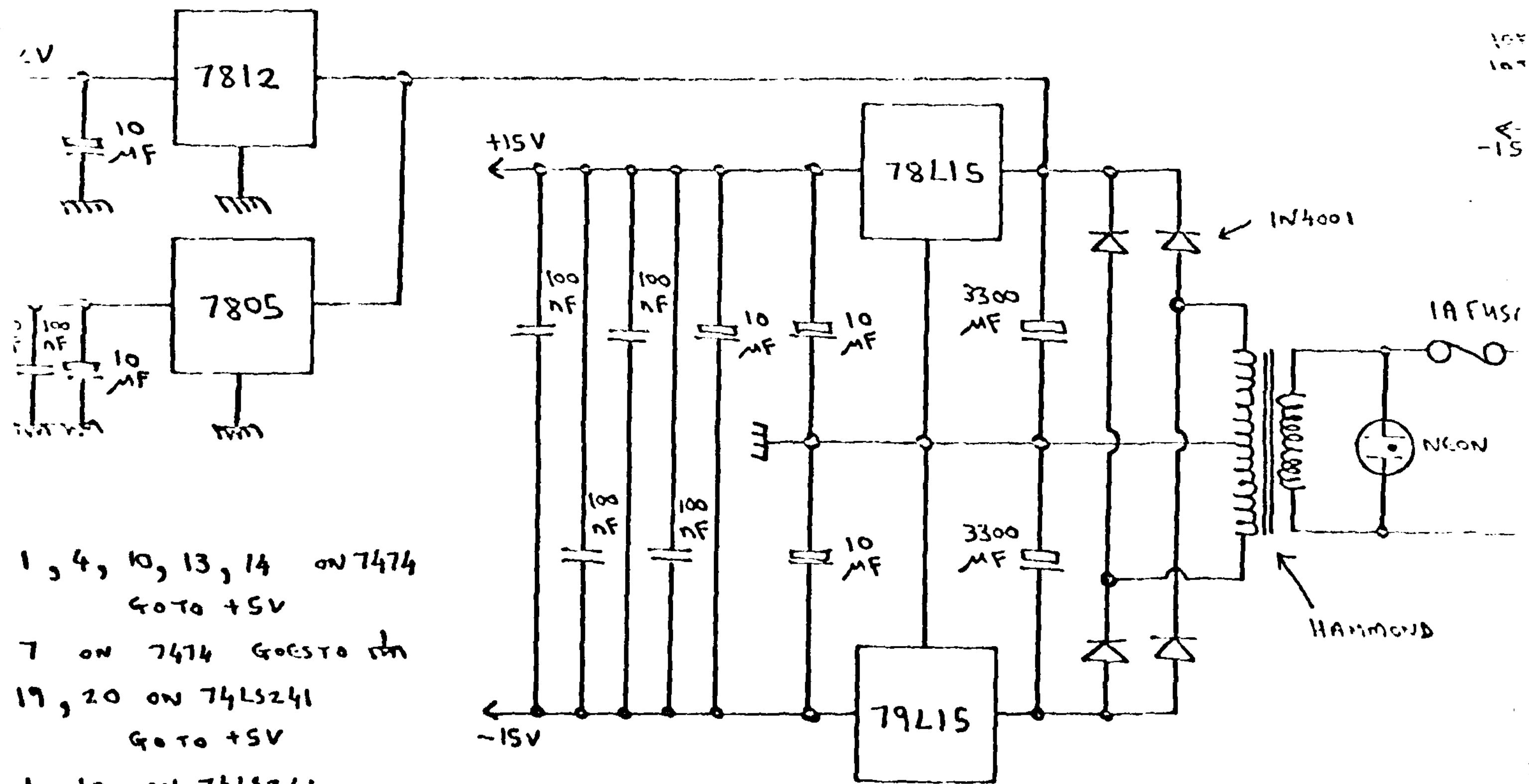
PINS 1, 4, 10, 13, 14 ON 7474 GO TO +5V

PIN 7 ON 7474 GOES TO ground

PINS 19, 20 ON 74LS241 GO TO +5V

PINS 1, 10 ON 74LS241 GO TO ground



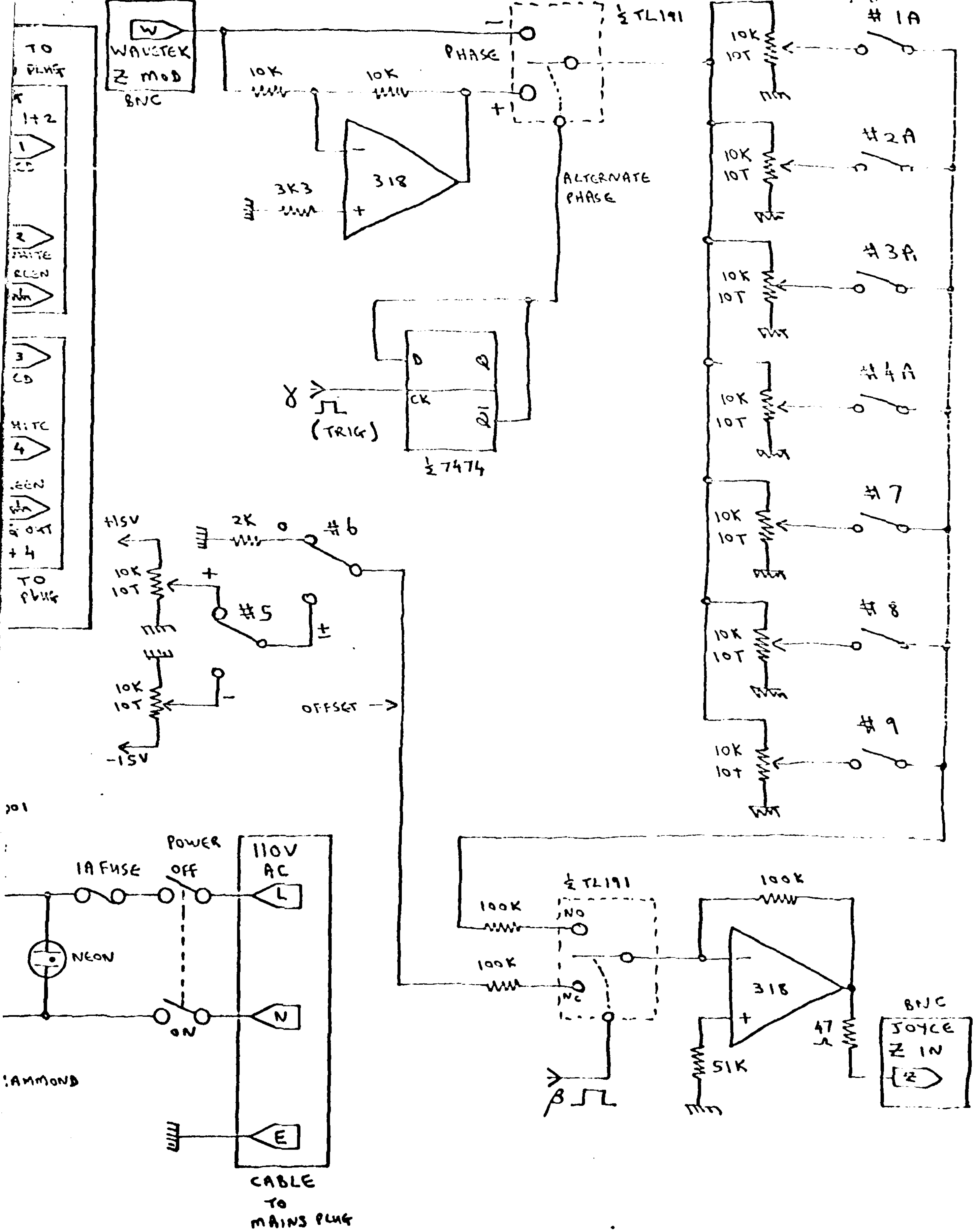


1, 4, 10, 13, 14 ON 7474
GO TO +5V

7 ON 7474 GOES TO

19, 20 ON 74LS241
GO TO +5V

1, 10 ON 74LS241
GOTO


TO
PLUG
1+2
1
2
3
4
TO
PLUG
W
WAVETEK
Z MOD
BNC
10K
10K
3K3
318
PHASE
½ TL191
ALTERNATE
PHASE
D
Q
CK
Q̄
γ
(TRIG)
½ 7474
#1A
#2A
#3A
#4A
#7
#8
#9
10K
10T
+15V
2K
#6
#5
±
-15V
OFFSET
1A FUSE
POWER
OFF
ON
NEON
110V
AC
L
N
E
CABLE
TO
MAINS PLUG
½ TL191
NO
NC
100K
100K
100K
318
47
51K
β
BNC
JOYCE
Z IN
Z

(d)

D. Regan

PUBLICATIONS

(not including abstracts)

Books

Regan, D. Evoked potentials in psychology, sensory physiology and clinical medicine. London: Chapman & Hall; New York: Wiley, 1972. 328 pp. Rpt. 1975.

Regan, D. The visual perception of motion. Oxford Psychology Series. Oxford University Press, in preparation.

Papers

1. Regan, D. Some characteristics of average steady-state and transient responses evoked by modulated light. Electroenceph. clin. Neurophysiol., 1966, 20, 238-248.
2. Regan, D. An apparatus for the correlation of evoked potentials and repetitive stimuli. Med. & biol. Engng., 1966, 4, 169-177.
3. Regan, D. An effect of stimulus colour on average steady-state potentials evoked in man. Nature, 1966, 210, 1056-1057.
4. Regan, D. A high frequency mechanism which underlies visual evoked potentials. Electroenceph. clin. Neurophysiol., 1968, 25, 231-237.
5. Regan, D. Chromatic adaptation and steady-state evoked potentials. Vision Res., 1968, 8, 149-158.
6. Regan, D. Evoked potentials and sensation. Perception & Psychophysics, 1968, 4, 347-350.
7. Regan, D. Evoked potentials and colour vision. 7th ISCERG Symp., Istanbul (1969), pub. by University of Istanbul (1971), pp. 37-50.
8. Regan, D. Chapters 3 & 4 in "Evoked potentials as indicators of sensory information processing". D.M. MacKay (Ed.), Neurosciences Research Bulletin, 1969, 7, No. 3.
9. Regan, D. & Heron, J.R. Clinical investigation of lesions of the visual pathway: a new objective technique. J. Neurol. Neurosurg. Psychiat., 1969, 32, 479-483.
10. Tweel, L.H. van der, Regan, D. & Spekreijse, H. Some aspects of potentials evoked by changes in spatial brightness contrast. 7th ISCERG Symp., Istanbul (1969), pub. by University of Istanbul (1971), pp. 1-11.
11. Regan, D. Evoked potential and psychophysical correlates of changes in stimulus colour and intensity. Vision Res., 1970, 10, 163-178.
12. Regan, D. Objective method of measuring the relative spectral luminosity curve in man. J. opt. Soc. Am., 1970, 60, 856-859.
13. Regan, D. & Heron, J.R. Simultaneous recording of visual evoked potentials from the left and right hemispheres in migraine. In A.L. Cochrane (Ed.), Background to migraine. London: Heinemann, 1970, 66-77.
14. Regan, D. & Cartwright, R.F. A method of measuring the potentials evoked by simultaneous stimulation of different retinal regions. Electroenceph. clin. Neurophysiol., 1970, 28, 314-319.
15. Regan, D. & Spekreijse, H. Electrophysiological correlate of binocular depth perception in man. Nature, 1970, 255, 92-94.
16. Regan, D. & Sperling, H.G. A method of evoking contour-specific scalp potentials by chromatic checkerboard patterns. Vision Res., 1971, 11, 173-176.

17. Regan, D. & Tyler, C.W. Wavelength-modulated light generator. Vision Res., 1971, 11, 43-56.

18. Regan, D. & Tyler, C.W. Some dynamic features of colour vision. Vision Res., 1971, 11, 1307-1324.

19. Regan, D. & Tyler, C.W. Temporal summation and its limit for wavelength changes: an analog of Bloch's law for color vision. J. opt. Soc. Am., 1971, 61, 1414-1421.

20. Regan, D. & Richards, W. Independence of evoked potentials and apparent size. Vision Res., 1971, 11, 679-684.

21. Regan, D. Evoked potentials to changes in the chromatic contrast and luminance contrast of checkerboard stimulus patterns. In G.B. Arden (Ed.), The visual system. New York: Plenum, 1972.

22. Regan, D. Evoked potentials to changes in chromatic contrast. Proc. GAIN Symp. on EPs to spatial contrast. Trace, 1972, 6, 20-28.

23. Regan, D. Cortical evoked potentials. Adv. Behav. Biol., 1972, 5, 177-192.

24. Spekreijse, H., van der Tweel, L.H. & Regan, D. Interocular sustained suppression: correlations with evoked potential amplitude and distribution. Vision Res., 1972, 12, 521-526.

25. Milner, B.A., Regan, D. & Heron, J.R. Theoretical models of the generation of steady-state evoked potentials, their relation to neuroanatomy and their relevance to certain clinical problems. Advances in Medicine and Biology, 1972, 24, 157-169.

26. Regan, D. Parallel and sequential processing of visual information in man: investigation by evoked potential recording. In Photophysiology, Vol. 8. New York: Academic Press, 1973, 185-208.

27. Regan, D. An evoked potential correlate of colour: evoked potential findings and single-cell speculations. Vision Res., 1973, 13, 1933-1941.

28. Regan, D. Evoked potentials specific to spatial patterns of luminance and colour. Vision Res., 1973, 13, 2381-2402.

29. Regan, D. Rapid objective refraction using evoked brain potentials. Invest. Ophthalmol., 1973, 12, 669-679.

30. Regan, D. & Richards, W. Brightness contrast and evoked potentials. J. opt. Soc. Am., 1973, 63, 606-611.

31. Regan, D. & Beverley, K.I. Disparity detectors in human depth perception: evidence for directional selectivity. Science, 1973, 181, 877-879.

32. Regan, D. & Beverley, K.I. Some dynamic features of depth perception. Vision Res., 1973, 13, 2369-2379.

33. Regan, D. & Beverley, K.I. The dissociation of sideways movements from movements in depth: psychophysics. Vision Res., 1973, 13, 2403-2415.

34. Beverley, K.I. & Regan, D. Evidence for the existence of neural mechanisms selectively sensitive to the direction of movement in space. J. Physiol., 1973, 235, 17-29.

34a. Beverley, K.I. & Regan, D. Selective adaptation in stereoscopic depth perception. J. Physiol., 1973, 232, 40-41P.

35. Regan, D. & Beverley, K.I. Relation between the magnitude of flicker sensation and evoked potential amplitude in man. Perception, 1973, 2, 61-65.

36. Regan, D. & Beverley, K.I. Electrophysiological evidence for the existence of neurones sensitive to the direction of depth movement. Nature, 1973, 246, 504-506.

37. Richards, W. & Regan, D. A stereo field map with implications for disparity processing. Invest. Ophthalmol., 1973, 12, 904-909.

38. Cartwright, R.F. & Regan, D. Semi-automatic, multi-channel Fourier analyser for evoked potential analysis. Electroenceph. clin. Neurophysiol., 1974, 36, 547-550.

39. Regan, D. Electrophysiological evidence for colour channels in human pattern vision. Nature, 1974, 250, 437-439.

40. Regan, D. & Spekreijse, H. Evoked potential indications of colour blindness. Vision Res., 1974, 14, 89-95.

41. Heron, J.R., Regan, D. & Milner, B.A. Delay in visual perception in unilateral optic atrophy after retrobulbar neuritis. Brain, 1974, 97, 69-78.

42. Beverley, K.I. & Regan, D. Temporal integration of disparity information in stereoscopic perception. Exp. Brain Res., 1974, 19, 228-232.

43. Beverley, K.I. & Regan, D. Visual sensitivity to disparity pulses: evidence for directional selectivity. Vision Res., 1974, 14, 357-361.

44. Regan, D. Visually evoked potential methods with clinical applications. Proc. 11th ISCERG Symp., Bad Neuheim (1973). Docum. ophthal., Series 4, 1974, 285-301.

45. Milner, B.A., Regan, D. & Heron, J.R. Differential diagnosis of multiple sclerosis by visual evoked potential recording. Brain, 1974, 97, 755-772.

46. Regan, D. Colour coding of pattern responses in man investigated by evoked potential feedback and direct plot techniques. Vision Res., 1975, 15, 175-183.

47. Heron, J.R., Milner, B.A. & Regan, D. Measurement of acuity variations within the central visual field caused by neurological lesions. J. Neurol. Neurosurg. Psychiat., 1975, 38, 356-362.

48. Regan, D., Schellart, N.A.M., Spekreijse, H. & van den Berg, T.J.T.P. Photometry in goldfish by electrophysiological recording. Vision Res., 1975, 15, 799-807.

49. Beverley, K.I. & Regan, D. The relation between discrimination and sensitivity in the perception of motion in depth. J. Physiol., 1975, 249, 387-398.

50. Regan, D. Recent advances in electrical recording from the human brain. Nature (Review article), 1975, 253, 401-407.

51. Regan, D., Milner, B.A. & Heron, J.R. Delayed visual perception and delayed visual evoked potentials in the spinal form of multiple sclerosis and in retrobulbar neuritis. Brain, 1976, 99, 43-66.

52. Regan, D., Varney, P., Purdy, J. & Kraty, N. Visual field analyser: assessment of delay and temporal resolution of vision. Med. & biol. Engng., 1976, 14, 8-14.

53. Regan, D. Latencies of evoked potentials to flicker and to pattern speedily estimated by simultaneous stimulation method. Electroenceph. clin. Neurophysiol., 1976, 40, 654-660.

54. Galvin, R.J., Regan, D. & Heron, J.R. A possible means of monitoring the progress of demyelination in multiple sclerosis: effect of body temperature on visual perception of double light flashes. J. Neurol. Neurosurg. Psychiat., 1976, 39, 861-865.

55. Galvin, R.J., Regan, D. & Heron, J.R. Impaired temporal resolution of vision after acute retrobulbar neuritis. Brain, 1976, 99, 255-268.

56. Regan, D. Fourier analysis of evoked potentials; some methods based on Fourier analysis. In J.E. Desmedt (Ed.), Visual evoked potentials in man: new developments. Oxford: Oxford University Press, 1977, 110-117.

57. Regan, D. Rapid methods for refracting the eye and for assessing visual acuity in amblyopia, using steady-state visual evoked potentials. In J.E. Desmedt (Ed.), Visual evoked potentials in man: new developments. Oxford: Oxford University Press, 1977, 418-426.

58. Regan, D. Evoked potential indications of the processing of pattern, colour, and depth information. In J.E. Desmedt (Ed.), Visual evoked potential in man: new developments. Oxford: Oxford University Press, 1977, 234-249.

59. Regan, D., Milner, B.A. & Heron, J.R. Slowing of visual signals in multiple sclerosis, measured psychophysically and by steady-state evoked potentials. In J.E. Desmedt (Ed.), Visual evoked potentials in man: new developments. Oxford: Oxford University Press, 1977, 461-469.

60. Regan, D. Speedy assessment of visual acuity in amblyopia by the evoked potential method. Ophthalmologica, 1977, 175, 159-164.

61. Regan, D. & Spekreijse, H. Auditory-visual interactions and the correspondence between perceived auditory space and perceived visual space. Perception, 1977, 6, 133-138.

62. Galvin, R.J., Heron, J.R. & Regan, D. Subclinical optic neuropathy in multiple sclerosis. Arch. Neurol., 1977, 34, 666-670.

63. Regan, D. Steady state evoked potentials. Proc. Symp. Electrophysiol. Techniques in Man. J. opt. Soc. Am., 1977, 67, 1475-1489.

64. Regan, D. & Milner, B.A. Objective perimetry by evoked potential recording: limitations. Electroenceph. clin. Neurophysiol., 1978, 44, 393-397.

65. Regan, D., Silver, R. & Murray, T.J. Visual acuity and contrast sensitivity in multiple sclerosis: hidden visual loss. Brain, 1977, 100, 563-579.

66. Regan, D. & Beverley, K.I. Looming detectors in the human visual pathway. Vision Res., 1978, 18, 415-421.

67. Cynader, M. & Regan, D. Neurones in cat parastriate cortex sensitive to the direction of motion in three-dimensional space. J. Physiol., 1978, 274, 549-569.

68. Regan, D. & Beverley, K.I. Illusory motion in depth: aftereffect of adaptation to changing size. Vision Res., 1978, 18, 209-212.

69. Hillyard, S.A., Picton, T.W. & Regan, D. Sensation, perception and attention: analysis using ERPs. In E. Callaway, P. Tueting & S.H. Koslow (Eds.), Event-related brain potentials in man. New York: Academic Press, 1978, 223-321.

70. Regan, D. Assessment of visual acuity by evoked potential recording: ambiguity caused by temporal dependence of spatial frequency selectivity. Vision Res., 1978, 18, 439-443.

71. Regan, D., Murray, T.J. & Silver, R. Effect of body temperature on visual evoked potential delay and visual perception in multiple sclerosis. J. Neurol. Neurosurg. Psychiat., 1977, 40, 1083-1091.

72. Arden, G.B., Bodis-Wollner, I., Halliday, A.M., Jeffreys, A., Kulikowski, J.J., Spekreijse, H. & Regan, D. Methodology of patterned visual stimulation. In J.E. Desmedt (Ed.), Visual evoked potentials in man. Oxford: Oxford University Press, 1977.

73. Regan, D. Investigations of normal and defective colour vision by evoked potential recording. Mod. Probl. Ophthal., 1978, 19, 19-28.

74. Regan, D. Visual evoked potentials and visual perception in multiple sclerosis. Proc. San Diego Biomed. Symp., Vol. 16. New York: Academic Press, 1977, 87-95.

75. Regan, D. New methods for neurological assessment: Overview. Proc. San Diego Biomed. Symp., Vol. 16. New York: Academic Press, 1977, 55-62.

76. Regan, D., Beverley, K.I. & Cynader, M. Stereoscopic depth channels for position and for motion. In S.J. Cool & E.L. Smith (Eds.), Frontiers in visual science. New York: Springer-Verlag, 1978, 351-372.

77. Regan, D. Evoked potentials in basic and clinical research. In A. Remond (Ed.), EEG informatics: a didactic review of methods and applications of EEG data processing. Amsterdam: Elsevier, 1977, 319-346.

78. Regan, D. Colour and contrast. In H. Spekreijse & L.H. van der Tweel (Eds.), Spatial contrast: report of a workshop. Pub. for Netherlands Royal Academy of Sciences. Amsterdam: North-Holland, 1977, 75-79.

79. Regan, D., Beverley, K.I. & Cynader, M. Stereoscopic subsystems for position in depth and for motion in depth. Proc. R. Soc. Lond. B, 1979, 204, 485-501.

80. Regan, D. & Tansley, B.W. Selective adaptation to frequency-modulated tones: evidence for an information-processing channel selectively sensitive to frequency changes. J. acoust. Soc. Am., 1979, 65, 1249-1257.

81. Regan, D. & Beverley, K.I. Visually-guided locomotion: psychophysical evidence for a neural mechanism sensitive to flow patterns. Science, 1979, 205, 311-313.

82. Beverley, K.I. & Regan, D. Separable aftereffects of changing-size and motion-in-depth: different neural mechanisms? Vision Res., 1979, 19, 727-732.

83. Beverley, K.I. & Regan, D. Visual perception of changing size: the effect of object size. Vision Res., 1979, 19, 1093-1104.

84. Regan, D. & Cynader, M. Neurons in area 18 of cat visual cortex selectively sensitive to changing size: nonlinear interactions between responses to two edges. Vision Res., 1979, 19, 699-711.

85. Regan, D. New visual tests in multiple sclerosis. In H.S. Thompson (Ed.), Topics in neuro-ophthalmology. Baltimore: Williams & Wilkins, 1980, 219-242.

86. Regan, D. & Beverley, K.I. Binocular and monocular stimuli for motion-in-depth: changing-disparity and changing-size inputs feed the same motion-in-depth stage. Vision Res., 1979, 19, 1331-1342.

87. Regan, D., Beverley, K.I. & Cynader, M. The visual perception of motion in depth. Sci. Am., 1979, 241, 136-151.

88. Regan, D. Detection and quantification of neuroophthalmological abnormalities using psychophysical measures of visual delay and temporal resolution. In S. Sokol (Ed.), Electrophysiology and psychophysics: their use in ophthalmic diagnosis. Intnl. Ophthal. Clinics. Boston: Little, Brown, 1980, 185-204.

89. Regan, D. Visual psychophysical tests in multiple sclerosis as an aid to diagnosis, localization of pathology, and assessment of experimental therapy. In Clinical applications of visual psychophysics (Proc. NAS/NRC Symp.) New York: Cambridge University Press, 1981.

90. Tansley, B.W. & Regan, D. Measurements of the sensitivities of information-processing channels sensitive to frequency change and amplitude change by a titration method. Perception & Psychophysics, submitted.

91. Beverley, K.I. & Regan, D. Visual sensitivity to the shape and size of a moving object: implications for models of object perception. Perception, 1980, 9, 151-160.

92. Regan, D., Whitlock, J., Murray, T.J. & Beverley, K.I. Orientation-specific losses of contrast sensitivity in multiple sclerosis. Invest. Ophthalmol. Vis. Sci., 1980, 19, 324-328.

93. Regan, D. & Beverley, K.I. Visual responses to changing size and to sideways motion for different directions of motion in depth: linearization of visual responses. J. opt. Soc. Am., 1980, 11, 1289-1296.

94. Regan, D. Control system and physiological monitoring applications of steady-state evoked potentials. In F.E. Gomer (Ed.), Biocybernetic applications for military systems. DARPA Conf, Chicago, 1978. St. Louis: McDonnell-Douglas Astronautics Corp. Report MDC E2191, 1980, pp. 175-202.

95. Tansley, B.W. & Regan, D. Separate auditory channels for unidirectional frequency modulation and unidirectional amplitude modulation. Sensory Processes, 1979, 3, 132-140.

96. Regan, D. & Beverley, K.I. Motion sensitivity measured by a psychophysical linearizing technique. J. opt. Soc. Am., 1981, 71,

97. Regan, D. Electrical responses evoked from the human brain. Sci. Am., 1979, 241, 134-146.

98. Beverley, K.I. & Regan, D. Device for measuring the precision of eye-hand coordination when tracking changing size. Aviation, Space & Environ. Med., 1980, 51, 688-693.

99. Raymond, J., Regan, D. & Murray, T.J. Abnormal adaptation of visual contrast sensitivity in multiple sclerosis patients. Can J. Neurol. Sci., in press.

100. Noseworthy, J., Miller, J., Murray, T.J. & Regan, D. Auditory brainstem responses in postconcussion syndrome. Arch. Neurol., 1981, 9,

101. Regan, D., Raymond, J., Ginsburg, A. & Murray, T.J. Contrast sensitivity, visual acuity and the discrimination of Snellen letters in multiple sclerosis. Brain, 1981, 104, 333-350.

102. Regan, D. Speedy evoked potential methods for assessing vision in normal and amblyopic eyes: pros and cons. Vision Res., 1980, 20, 265-269.

103. Petersik, J.T., Beverley, K.I. & Regan, D. Insensitivity of changing-size channels to spatial contrast. Vision Res., 1981, in press.

104. Petersik, J.T., Regan, D. & Murray, T.J. Double-flash thresholds as a function of field size in multiple sclerosis. Invest. Ophthalmol. Vis. Sci., in prep.

105. Beverley, K.I. & Regan, D. Temporal selectivity of changing-size channels. J. opt. Soc. Am., 1980, 11, 1375-1377.

106. Beverley, K.I. & Regan, D. Adaptation to incomplete flow patterns. Perception, 1981, in press.

107. Regan, D. Evoked potentials and perception. Can. J. Psychol., 1981, 35,

108. Cynader, M. & Regan, D. Neurons in cat visual area 18 tuned to the direction of motion in depth: effect of positional disparity. Vision Res., submitted.

109. Regan, D. & Cynader, M. Neurons in cat visual area 18 tuned to the direction of motion in depth: effect of stimulus speed. Invest. Ophthalmol. Vis. Sci., in press.

110. Regan, D. Electrophysiology and psychophysics of motion in depth. Proc. 18th ISCEV Symp., Amsterdam, 1980. Docum. Ophthal., in press.

111. Regal, D.M., Tibbles, J.A.R. & Regan, D. Comparison of evoked potentials in a visually-disordered infant and his normally-sighted twin.

112. Regan, D. The concept of visual channels; its relevance to ophthalmology and the performance of skilled tasks involving eye-limb coordination. Psych. Rev., submitted.

113. Regan,D. Psychophysical tests of vision and hearing in patients with MS. Demyelinating diseases: Clinical and basic electrophysiology. Proc. Vail Conf., MS Society of U.S.A. Raven Press, 1981.

114. Kruk, R., Regan, D., Beverley, K.I. & Longridge, T. Correlations between visual test results and flying performance on the Advanced Simulator for Pilot Training (ASPT). Aviation, Space & Environ. Med., in press.

115. Quine, D.B., Regan, D. & Murray, T.J. Delayed auditory tone perception and delayed BAEPs in multiple sclerosis. Submitted.

116. Quine, D.B., Regan, D., Beverley, K.E. & Murray, T.J. Auditory FM channel loss in multiple sclerosis: one possible cause for problems in understanding speech. Sensory Processes, submitted.

117. Regan, D., Beverley, K.I., Kruk, R. & Longridge, T. The relevance of the channel theory of vision for the design of simulator imagery. Proc. Image II Conf., Arizona 1981.

118. Regan, D. Comparison of transient and steady-state methods. Proc. N.Y. Acad. Sci., 1982, in press.

119. Regan, D. Binocular vision. In Encyclopaedia of Physics. Pergamon Press, 1982.

120. Regan, D. & Beverley, K.I. How we avoid confounding the direction we are looking with the direction we are moving. Science, submitted.

121. Kaufman, L. & Regan, D. Visual perception of complex motion. In Handbook of vision. In preparation.

122. Regan, D. Visual evoked potentials. In Handbook of electrophysiology. Elsevier, 1982. In preparation.

123. Quine, D.B., Regan, D. & Murray, T.J. Auditory loss specific to frequency change in patients with multiple sclerosis and noise-induced hearing loss.

(e) LIST OF PROFESSIONAL PERSONNEL ASSOCIATED WITH THE RESEARCH EFFORT

D. Regan, D.Sc. (Higher doctorate in Science & Medicine, London, 1974); Ph.D. (Physics, Imperial College, London, 1964); M.Sc., DIC (Physics, Technical optics, Imperial College, London, 1958); ARCS, B.Sc. (Physics, Imperial College, London, 1957).

(f) INTERACTIONS

Invited participant in Workshop on visual aspects of flight simulation, NASA/NATO, Ames Research Center, California (1980).

Invited speaker at Workshop on Visual Cues in Flight Simulation, NRC Committee on Vision, Phoenix, Arizona (1980).

Invited speaker at Atlantic Provinces Ophthalmologists Society annual meeting, Halifax, Canada (1980).

Invited lecture at Workshop on Physiological Basis of Evoked Potentials, Sloane Foundation, Carmel, California (1980).

Invited lecture on physiology of motion and depth vision, Satellite Symposium of International Physiological Congress, Braunlage, West Germany (1980).

Invited lecture on the physiology of binocular vision, annual meeting of the International Society for Clinical ERG, Amsterdam (1980).

Invited lecture on motion perception and skilled tasks. Concordia University, Montreal (1980).

Visiting Professor series, invited lecture to Ophthalmology Department, Tufts University, Boston (1981).

Two invited lectures on visual diagnostic methods at Neuro-ophthalmology Course, Bascom Palmer Eye Institute, Miami (1981).

Invited lecture on visual and auditory tests in multiple sclerosis at a Workshop on Basic and Clinical Electrophysiology of Demyelinating Disease, U.S. Multiple Sclerosis Society, Vail, Colorado (1981).

Invited lecture at Evoked Potentials Conference, McMaster University, Hamilton, Ontario (1981).

Invited lecture on motion in depth. Neurosciences Program, University of Wisconsin, Madison (1981).

(With M. Cynader). Lecture on motion in depth neurons to the Association for Research in Vision and Ophthalmology (ARVO), Sarasota (1981).

Invited lecture on evoked potentials, New York Academy of Sciences, New York City (1981).

Discussion and presentation on evoked potentials at Wright-Pattern Air Force Base Seminar (1978). Seminar at Williams AFB (1979). Meeting on vision in aviation, Williams AFB (1980). Member of NRC Committee on visual simulation in flight training. Member of NIH (NEI) Ophthalmology panel writing 1981-86 five year plan for funding.

(g) PATENTS

No patents arising from this grant.

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